Founded 1925
Incorporated
by Royal Charter 1961
To promote the advancement of radio, electronics and kindred subjects by the exchange of information in these branches of engineering

Volume 52 Number 10 October 1982

The Radio and Electronic Engineer

The Journal of the Institution of Electronic and Radio Engineers

'Big Brothers' Wanted

NO doubt many members will relate this heading to George Orwell's '1984', but there is no cause for alarm—the Institution is seeking 'Big Brothers' in the family sense. Nevertheless, the Orwellian allusion is relevant, and not merely a device to attract attention. The UK engineering profession has a Big Brother in the shape of the Council of Engineering Institutions/Engineers Registration Board. True, that body may eventually be replaced by the new Engineering Council, which in turn may ultimately be required to abide by the rules of an even more demanding Big Brother in Brussels if UK-registered engineers are to enjoy parity of recognition with their counterparts elsewhere in the EEC. It is with these possible developments in mind that the Engineers Registration Board has, during the past five years or so, become increasingly concerned that its rules must not only be obeyed, but be manifestly seen to be obeyed. That is the motive behind the recently introduced programme of accreditation of UK engineering degree courses and the new involvement of the ERB in the assessment of the training of registered engineers.

In the past it has been sufficient that the Institution itself should be satisfied that those whom it elects as Fellows, Members and Associate Members have met the training requirements for admission to those classes of membership: in the future it must be able, if required, to produce evidence to convince the ERB that it has abided by that body's criteria in making its judgement. This in turn means that applicants for admission to the registerable classes of membership will be required to produce authenticated evidence of training received.

Our senior members need not be reminded of the clause in the Institution's Rules of Professional Conduct which states that Chartered Electronic Engineers 'Shall be prepared to further the education and training of candidates for the qualification of Chartered Electronic Engineer', and it is with this in mind that we now appeal to them to offer their services in promoting, supervising, or monitoring the training of individual Students and Graduates by:

encouraging employers to submit their training schemes to the Institution for approval;

assisting in the supervision of individual trainees in IERE-approved schemes, either at their own place of employment or elsewhere;

acting as Tutor to those trainees not in IERE-approved schemes.

It is in the context of the third of these possibilities that the Institution believes the greatest need for 'big brothers' will arise. If, therefore, you consider that you would be able to direct and/or monitor the training of a young engineer in one of the many small companies which cannot offer a comprehensive training programme, please complete the form contained in this issue (p. iv), so that you may be sent more details.

K.J.C.

NOMINATIONS FOR ELECTION TO COUNCIL

In accordance with Bye-Law 43 the Council's nominations for election to the 1982–83 Council were notified to Corporate Members in the June issue of the Institution's Journal

FOR RE-ELECTION AS PRESIDENT

Harry Edward Drew, C.B., Hon.C.G.I.A. (Fellow 1948, Member 1944) received his basic engineering training as an Apprentice in the Royal Air Force and later served at the Air Ministry Experimental Station at Bawdsey Manor. During the later war years from 1943 to 1946 he became Works Manager of the Radio Production Unit at Woolwich and then Officer in Charge of the Research Prototype Unit. After the war he moved to the Ministry of Supply where he was Assistant Director of Electronics Production in 1951, and then Director in 1959. In 1964 he was appointed Director of Technical Costs and two years later he was promoted to the post of Director-General, Quality Assurance, in the then Ministry of Technology. He was made a C.B. in 1970. Following the recommendations of the Raby Committee, in September 1970 Mr Drew became the first Executive Officer of the newly formed Defence Quality Assurance Board, the post he held until his retirement from the Civil Service in January 1972. As founder chairman of the European Components Quality Assurance Committee (ECQAC), he was instrumental in having BS 9000 recommendations accepted in Europe.

Since his retirement Mr Drew has held several directorships in industry and is currently a director of Export Packing Services (R&D) Ltd and of Quality Audit and Advisory Services Ltd; he is also an independent industrial consultant.

Mr Drew has taken an active part in Institution affairs for many years. He was a member, and subsequently Chairman, of the Membership Committee and he served for several years as a member of Council. He was a member of the Finance Committee from 1965–69 and Vice-President 1979–81. Mr Drew is an Honorary Fellow and Past President of the Institution of Industrial Managers, a Vice-President of the Institution of Works Managers, a Fellow of the Institution of Production Engineers, and a Companion of the British Institution of Management. He is also a Past Master of the Worshipful Company of Scientific Instrument Makers and in 1974 an Honorary City and Guilds Insignia Award was conferred upon him.

FOR RE-ELECTION AS VICE-PRESIDENTS

Colonel William Barker (Fellow 1978, Member 1966, age 52) is Director of Engineering at the Services Sound and Vision Corporation.*

Leonard Alfred Bonvini (Fellow 1969, Member 1963, Graduate 1958, age 50) is with Government Communication Headquarters.*

Derek Leslie Anthony Smith, B.Sc. (Eng.) (Fellow 1971, Member 1956, Student 1947, age 60) is Principal of Acton Technical College.*

Group Captain James Martin Walker, MRAeS, RAF (Fellow 1981, Member 1966, Graduate 1957, Student 1956, age 47) is Deputy Director of Signals 3 (Air) in the Ministry of Defence.*

FOR ELECTION AS VICE-PRESIDENTS

Ronald Larry, MIEE (Fellow 1979, Member 1953; age 58) has been Head of General Services in the Designs Department of the British Broadcasting Corporation since 1967.

After wartime service in the Armed Forces Mr Larry spent several years in industry before joining the Engineering Planning and Installation Department of the British Broadcasting Corporation in 1951. For the next few years he was closely involved in the many design and installation problems posed by the post-war expansion of the television service and prior to his present appointment was responsible for the design and production of the Colour Television Mobile Control Rooms required for the start of the Colour Service.

Mr Larry was Chairman of the Communications Group Committee from 1970–73 and is currently on the Executive Committee. He is also a member of the Professional Activities and Recording Group Committees. He was first elected a member of the Council in 1970 and again in 1980 and is Chairman of the Organizing Committee for the series of Conferences on Video and Data Recording, the fourth of which was held at the University of Southampton in April of this year.

* See Journal for October 1981


W. BARKER


L. A. BONVINI


D. L. A. SMITH


J. M. WALKER

Robert William Wray, B.Sc., MIEE (Fellow 1966, Member 1961, Graduate 1957, age 55) is the owner of the firm of R. William Wray & Associates—Patent and Trade Mark Agents, Engineers—in Ottawa, Canada.

Mr Wray joined the British Broadcasting Corporation in 1943 as a Technical Assistant in the Operations and Maintenance Department (Transmitters). In 1946 he commenced three years National Service in the Royal Air Force as a Radar Fitter and whilst in Egypt studied for University entrance. He subsequently studied at the then University College, Hull and was awarded a B.Sc. degree by London University. He also obtained a Higher National Certificate in Electrical Engineering at Wimbledon Technical College.

After taking a Graduate Training Course with Pye in Cambridge, Mr Wray worked in the computer section of the Research and Development Laboratories at Decca Radar and was co-inventor of certain computer circuits. This stimulated an interest in patents and he joined the Patent Department of IBM (United Kingdom), subsequently obtaining experience in private practice and qualifying as a Chartered Patent Agent in 1961. Mr Wray joined the Patent Department of a large legal firm in Ottawa, Canada in 1964 and in 1973 established his own firm.

Mr Wray is a Member of the Institution of Electrical Engineers, a Fellow of the Chartered Institute of Patent Agents (United Kingdom), and Fellow of the Patent and Trademark Institute of Canada. He is a Member of the Association of Professional Engineers of Ontario, and a Member of the Engineering Institute of Canada as well as of several international associations concerned with industrial property. He became Secretary of the Ottawa Section of the IERE in 1965 and its Chairman in 1968, from which time he has also acted for the Institution in supervising the Canadian Office. Mr Wray served as Honorary Secretary of the Canadian Division from 1966 to 1975 and since 1975 has been Chairman of the Canadian Division.


R. LARRY


R. W. WRAY


S. R. WILKINS

FOR RE-ELECTION AS HONORARY TREASURER

Sydney Rutherford Wilkins (Fellow 1942, Member 1935, Associate 1934, age 70) was Managing Director of Fleming Instruments Ltd until his retirement earlier this year. He was first elected Honorary Treasurer in 1973.

FOR ELECTION AS ORDINARY MEMBERS OF COUNCIL
Class of Fellows

Professor David Philip Howson, D.Sc., M.Sc., B.Sc., FIEE (Fellow 1969, Member 1961, age 51) took his B.Sc. degree at Bristol University in 1952. He then spent five years in industry as a design engineer with Standard Telephones & Cables before taking his M.Sc. in information engineering at Birmingham University. From 1958 to 1967 he was successively Lecturer and Senior Lecturer at Birmingham University. In 1968 he was appointed to his present position as Professor of Electrical and Electronic Engineering at the University of Bradford, having obtained his D.Sc. from the University of Birmingham in the same year. From 1970–75 he was Dean of Engineering at Bradford. Prof. Howson is the author or co-author of many

D. P. HOWSON

G. A. JACKSON

papers and articles on various aspects of communications engineering, in which field lie his current research interests. He has been Chairman of the West Midland Section Committee and he has recently rejoined the Education and Training Committee.

Gerald Alfred Jackson, B.Sc., MIEE (Fellow 1978, age 56) graduated from University College, Exeter, in 1945 with a London University external honours degree in physics. He worked for six years in the magnetic materials laboratory at Standard Telephones and Cables and joined the then Electrical Research Association (now ERA Technology) in May 1952. While at ERA he has worked on problems of electromagnetic interference including techniques of measurement, instrumentation and screening and has published papers on various aspects of the subject. He is now Manager of the Electromagnetic Interference Department and is involved with work of national and international standardization as Vice-Chairman of CISPR, Chairman of CISPR SCB (ISM equipment) and of GEL/111, the BSI technical committee on e.m. interference. He has served on the organizing committees for the IERE conferences on Electromagnetic Compatibility in 1978/80/82, being chairman for the last two events.

FOR ELECTION AS ORDINARY MEMBERS OF COUNCIL
Class of Members

Arthur Frank Dyson, Dip.Elec. (Member 1968, Graduate 1962, age 49) studied for his Diploma in Electronics of the University of Southampton while a Student Apprentice with British Thomson-Houston, Rugby, and after qualifying in 1959 joined B T H Semiconductors, Lincoln. He next spent two years with Erie Technological Products in Erie, Pennsylvania, returning to the UK in 1963 to become Assistant General Manager of Erie Electronics, Great Yarmouth, and subsequently Technical Director. The company is now part of ITT and Mr Dyson is Group Technical Manager of ITT Capacitors. Since 1974 Mr Dyson has been a member of the Professional Activities Committee, the Components and Circuits, and Electronics Production Technology Group Committees; he was chairman of the latter from 1975 to 1978 and he has recently taken over the chair again following the death of his successor. He has contributed papers to several colloquia, one of which, on Resistors, was published in the Journal in April 1974.

Professor Peter Alfred Payne, Ph.D. (Member 1976, Graduate 1965, age 46), following some ten years in the electronic industry with a number of companies including G. and E. Bradley and EMI Electronics, joined the Dynamics Analysis Group of the University of Wales Institute for Science and Technology in 1967. Here he carried out research into control system testing techniques for which he was awarded the degree of Ph.D. in 1972. In 1975 Dr Payne became Head of the Bioengineering Unit of the University Hospital of Wales, Cardiff. He was appointed to the chair of Instrumentation and Analytical Science at the University of Manchester Institute of Science and Technology in 1980. He is author and co-author of numerous papers and has served on a number of Institution conference committees; he was Chairman of the Organizing Committee for the conference on The Influence of Microelectronics on Measurements and Transducer Design in July this year. Professor Payne is Chairman of the Measurements and Instruments Group Committee and also serves on the Medical and Biological Electronics Group Committee. He has been a recipient of Institution premiums on three occasions.

A. F. DYSON

P. A. PAYNE

M. M. ZEPLER

A. R. B. NORRIS

D. R. CAUNTER

Matthew Martin Zepler, M.A., Dip.Elec. (Member 1967, age 47) read natural sciences at Cambridge University followed by a Diploma in Electronics at Southampton University in 1960. Since then he has been at the Roke Manor Research Laboratories of the Plessey Company, engaged on a variety of research topics. These have included the development of a miniature atomic frequency standard, interference cancellation systems, computer controlled antenna arrays, satellite navigation and nuclear hardening of military equipments. He has presented a number of papers at international conferences. His current interests include military communications and electronic warfare systems.

Mr Zepler has been very active in Institution activities, having served for some years on the Membership Committee and the Communications Group Committee of which he is currently the Chairman; he has also served on the organising committees of a number of Institution Conferences. He has previously been a member of Council (1974–76).

FOR ELECTION AS AN ORDINARY MEMBER OF COUNCIL
Class of Associate Members

Commander Alan Richard Bradley Norris, RN(Retd) (Associate Member 1973, Associate 1959, age 55) qualified as a Weapon and Electrical Engineer in the Royal Navy in 1953, and during his career specialized in weapon control systems, radar and radio communications. He underwent postgraduate training at the RN College, Greenwich, and attended the National Defence College in 1972.

On completion of training Cdr. Norris worked on the installation of shore radio transmitters in Hong Kong. Between 1955 and 1962 he was Electrical Engineer in a destroyer operating in the Far East and Mediterranean, and then was associated with radar development at the Admiralty Surface Weapons Establishment (ASWE). Subsequently, he became the Missile Systems Engineer in a guided missile destroyer. From 1965, as Staff Engineer (Weapons), he was responsible for monitoring and assessment of the material efficiency of fleet weapons systems, and then in 1969 he became responsible for course design at the RN Electrical School. After this he returned to project work at ASWE on computer-assisted command and control and data processing systems. He spent a further period at sea as head of the Electrical Engineering Department of an aircraft carrier and then went to Washington as RN Liaison Officer with the US Navy for satellite communications and electronic warfare projects.

Cdr. Norris rejoined ASWE in 1977 as Naval Engineer for communications projects, responsible for project definition, equipment specification, system integration, acceptance into service and upkeep. He left the Navy in 1980 and joined the Design and Projects Division of Vickers as a Project Manager, where he is now involved with ship weapons system engineering and training projects.

Cdr. Norris has served on the Aerospace, Maritime and Military Systems Group Committee for the past four years.

FOR ELECTION AS AN ORDINARY MEMBER OF COUNCIL
Class of Associates

Denis Reginald Caunter (Associate 1980, age 57) was initially employed at the Atomic Energy Research Establishment in 1947 as a Scientific Assistant. After service in the RAF as a Radar Mechanic he joined the Marconi Wireless Telegraph Company in 1952 and became a section leader in the Installation Design Team of the Radar Division engaged on military projects including the updating of the NATO and UK radar defence chains.

Mr Caunter joined Cossor Electronics at Harlow in 1963 to form an Installation Design Department in the Service and Installation Division. He was appointed Special Projects Manager of that Division in 1972 handling specific projects on radar, communications and instruments. He is at present engaged in a management team on a co-ordination task for radar defence work.

Members' Appointments

CORPORATE MEMBERS

S. G. Bird, B.Sc. (Fellow 1975, Member 1967) who has been with Cable & Wireless since 1945, latterly as Group General Manager (Cables and Submarine Systems), has been appointed Head of Technology and Engineering Division.

J. Helszjan, Ph.D., D.Sc. (Fellow 1969, Associate Member 1965) who is an independent consultant and a part-time Research Fellow at Heriot Watt University, Edinburgh, has been promoted to a personal chair as Professor of Microwave Engineering in the Department of Electronic and Electrical Engineering at the University.

Group Captain R. C. Travis, M.B.E., B.Sc., RAF (Fellow 1982, Associate Member 1962) who was formerly Senior Administrative and Training Staff Officer at the RAF College, Cranwell, is now Officer Commanding, RAF School of Education and Training Support at RAF Newton.

Sqn Ldr D. F. Grimston, RAF (Member 1971) is now on the staff of NATO Headquarters, COMIBERLANT, Portugal. He previously held a staff appointment at the Ministry of Defence.

M. D. K. Kendall-Carpenter, O.B.E. (Member 1973, Associate 1969) who was Vice Principal, Cable & Wireless Engineering College at Porthcurno, recently retired after 37 years in engineering and training at Cable & Wireless. He has undertaken the task, as Honorary Curator, of establishing a Museum of Submarine Telegraphy, covering the century 1860–1960 at Porthcurno. 'PK' as it has been known to generations of Cable & Wireless staff, is an appropriate site for such a museum as it was the main cable-head of the old Eastern Telegraph Company. Mr Kendall-Carpenter himself joined C & W at Porthcurno as a local boy entrant.

Lt Cdr R. W. Ditchfield, D.Phil., M.A., RN (Member 1975) has taken up an appointment as UK Representative on the Permanent Interoperability Working Group of the Allied Data Systems Interoperability Agency, NATO, Brussels. For the past five years Cdr Ditchfield has been with the Hydrographic Department of the Ministry of Defence.

S. W. Kong (Member 1973, Graduate 1969), Head of the Department of Electrical Engineering of Kwai Chung Technical Institute, Hong Kong since 1977, has been appointed Vice Principal of the Institute.

B. D. Krause (Member 1975, Graduate 1970) is now a Principal Consultant with Reliability Consultants, formed recently by a group of engineers who have bought out the consultancy operations of Plessey Assessment Services of Titchfield.

B. W. Lovell (Member 1974) who has been in Hong Kong since 1980, has returned to the United Kingdom and is now a Technical Officer, Electronics, at the Foreign and Commonwealth Office in London. While in Hong Kong Mr Lovell took an active part in affairs of the Institution's local section, latterly holding the post of Programme Secretary.

E. G. Parker (Member 1981, Graduate 1972) who has been with Northern Telecom Canada since 1978, is now Works Manager, Communication Cable Division, Kingston Works. He was previously Manufacturing Manager at Northern Telecoms Saskatchewan Plant.

J. D. Parsons, B.Sc., M.Sc.(Eng.) (Member 1967), Reader in Radiocommunications at the University of Birmingham, has been appointed to a Chair of Electrical Engineering at the University of Liverpool from 1st October 1982. Professor Parsons was educated at University College, Cardiff and King's College, London. Following a period at GEC Applied Electronics Laboratories, Stanmore, he took up his first teaching appointment at the Polytechnic, Regent Street in 1962. He moved to the University of Birmingham in 1969 where his major research interests have been concerned with various aspects of mobile radio communication. He has contributed several papers to the Journal, served on Conference Organizing Committees and is a past chairman of the Institution's West Midlands Section.

D. G. Pinder (Member 1971) has taken up an appointment as Project Manager of the S.N.C. Group in Toronto, Canada.

Sqn Ldr F. B. Sanson, RAF (Retd) (Member 1973, Graduate 1970) formerly a Senior Systems Specialist with the Future Systems Team of Marconi Avionics, has taken up an appointment in programme management of the Airworthiness Branch of Transport Canada based in Ottawa.

Major J. M. Sweetman, B.Sc., R.Sigs, (Member 1973, Graduate 1966) who has been a Staff Officer of Project Wavell at the Ministry of Defence (Procurement Executive) since 1979, has been appointed Training Major, 39 (City of London) Signal Regiment (Volunteers).

P. A. Wade (Member 1973) has been appointed General Manager for Timeplex Inc. at the factory in Dublin which manufactures a wide range of data communications equipment. He was previously Operations Director with Dataproducts (Dublin).

P. G. B. Whitham, M.A. (Member 1978) has been appointed Engineering Manager of Remsdaq, Deeside, Clwyd, where he will be responsible for all development work, including hardware and software for projects and engineering services. Mr Whitham previously held appointments with Marconi Avionics, Borehamwood and Marconi Space and Defence Systems at Kidsgrove.

Lt Cdr R. Wright, RN (Member 1973, Graduate 1970) who was Staff Officer, Combat System Engineering at the Maritime Command Headquarters in Halifax, Nova Scotia, has returned to the United Kingdom and has been posted to the Staff of Director Underwater Weapons Production (Naval), AUWE, Portland as Deputy Manager Trial, Seabed Operations Vessel.

NON-CORPORATE MEMBERS

L. E. Blogg (Graduate 1969) is now Product Regulations Engineer with Hewlett Packard at Wokingham.

G. T. Elsmere (Graduate 1970), formerly Technical Training Officer with Rank Xerox, is now a Graduate Training Officer with British Aerospace, Dynamics Group, Hatfield.

G. W. Hind, B.Sc. (Graduate 1981), formerly a Quality Assurance Representative (PTO 3) with the Ministry of Defence, has been appointed to the post of Assistant Project Officer, Thermal Imaging Repair Facility at RSRE, Malvern.

Brigadier M. H. Mackenzie-Orr, O.B.E., G.M. (Graduate 1965) has been appointed President of the Australian Ordnance Council in Canberra. His previous appointment was Director of the Joint Services School of the Australian Armed Forces.

C. I. Onwuachu (Graduate 1972) has been promoted to Assistant Chief Engineer in the Posts and Telecommunications Department of the Federal Ministry of Communications, Nigeria, and is in charge of all telecommunications engineering activities in Cross River State, Nigeria.

Lt C. R. Thorpe, B.Sc., RN (Graduate 1978) has completed a tour of duty as Deputy Weapons Engineer Officer, HMS *Diomede*, and is now with the Procurement Executive, Ministry of Defence (Navy) at Bath.

H. J. Lawrence (Associate Member 1973, Associate 1963) has taken up an appointment as Projects Controller, Airspace Control Division, with Marconi Radar Systems having previously held the post of Project Manager with the company.

Z. O. Odongo (Associate Member 1979) who has been with the Kenya External Telecommunications Company since 1972, has been appointed Senior Maintenance Engineer and Acting Engineer in Charge of the Central Telegraph Office in Nairobi.

R. Stewart (Associate Member 1961) has been appointed Technical Director of TACTICO, Edinburgh.

The 56th Annual Report of the Council of the Institution

For the year ending 31st March 1982

The Council is pleased to present the 56th Annual Report of the Institution—the 21st since its Incorporation by Royal Charter. The Annual General Meeting will be held on Thursday, 28th October 1982, at the London School of Hygiene and Tropical Medicine, commencing at 6 p.m.

INTRODUCTION

THE Institution's Annual Report has been presented in the same format for 40 years without adverse criticism from the membership and with ample feed-back evidence to show that it is read and appreciated by many. The familiar pattern is, therefore, continued this year and it is hoped that readers will find in the individual committee reports which follow this introduction all the information they need to encourage them to continue their support of the Institution's work in the very testing times in which we all find ourselves at present.

The Institution's fifty-sixth year has been marked by doubts and hindrances engendered by both the continuing delay in the establishment of the Government answer to the Finniston Inquiry and by the pervasive effects of the international recession which has put such a heavy damper on much of our learned society work. The former problem is touched on in the Executive Committee's report, and developed in rather more detail in the section devoted to the affairs of the Education and Training Committee. All that need be said here in this context is that the Institution has made it clear that it stands ready to help Sir Kenneth Corfield's Engineering Council in any and every way consistent with the terms of our Royal Charter and Bye-laws. As to the other main problem—the influence of the recession on IERE activity—the scale of which is plainly evident in the report of the Professional Activities Committee, it is gratifying to report that as the year ended, the indications were that the tide had turned: indeed, advance bookings for the first major conference of the coming year were well up to the level experienced when the same subject, namely, Video and Data Recording, was last explored in 1979.

The Institution's financial health is considered in all necessary detail in the last section of the Executive Committee report, but special mention must be made here of the Council's appreciation of the Corporate and Associate members' most generous response to the Secretary's summer appeal for donations to reduce the final element of the General Fund accumulated deficit whilst the level of members' subscriptions was being held down for a further year. Well over half the membership to whom the appeal was addressed responded at the modest level suggested by the Secretary; and many others donated sums well in excess of a year's subscription for their class of membership. All of which was very encouraging—not only for financial reasons but also for the clear indication provided in the accompanying correspondence of the deep-rooted loyalty of so many of the members and their professional support for the ideals, standards and learned society work of their Institution.

Just as financial considerations govern the scale of the Institution's work, so does the devolution of its cause by its secretariat govern the efficiency with which that work is carried out; and it is with this in mind that the Council is very sorry to have to report that the Institution's Secretary, Air Vice-Marshal Sinclair Davidson, completed his contract term of service at the close of the year under report and is unable to extend the formal agreement for a further term. A working group nominated by the Council has initiated action to appoint a new Secretary and Air Marshal Davidson has agreed to continue in office on an informal basis until the task of that working group has been completed to Council's satisfaction.

EXECUTIVE COMMITTEE

The Profession The major issue affecting the engineering profession continued to be the drafting of the Royal Charter for the establishment of the Engineering Council, a final version of which was eventually submitted by the Secretary of State for Industry to the Lord President of the Privy Council.* Her Majesty The Queen subsequently signified her intention to grant the Royal Charter at a meeting of the Privy Council held on 28th October 1981, and the Engineering Council was

* *The Electronics Engineer*, no. 35, 20th August 1981

formally established on 27th November 1981, with its first seventeen members appointed under the chairmanship of Sir Kenneth Corfield.*

Having been closely involved in the many discussions, mainly within the Council of Engineering Institutions and through it with the Department of Industry, leading up to the formation of the new governing body for the profession, the Executive Committee felt that the Charter granted to the Engineering Council represented as fair a compromise as possible. There remained some reservations, however, in that much would depend on the manner in which the new body framed its bye-laws, e.g. in determining the standards and criteria for education, training and experience, the grouping of Institutions in related disciplines and the 'lead' Institution in those groups, sources and scale of financing, etc. It would therefore be imperative for the implications of these bye-laws to be carefully studied, and this the Executive Committee was resolved to do.

Designatory Letters for Associate Members At the Annual General Meeting on 29th October 1981, resolutions to amend the Institution's Charter and Bye-laws to enable Associate Members registered as Technician Engineers by the Engineers Registration Board to use designatory letters were unanimously approved by the corporate membership.† In due course these resolutions were allowed by Her Majesty and the Privy Council, and such members may henceforth append to their names the designation 'T.Eng.(CEI), A.M.I.E.R.E.'.

Scholarship Funding The Executive Committee was pleased to note the decision of the Trustees of the Leslie H. Paddle Scholarship Fund that the first award should be made to a post-graduate scholar at the University College of Swansea. This would enable Mr Robin Alston at the Department of Electrical and Electronic Engineering there to continue his work on virtual instrumentation, which would form the basis of a thesis for his master's degree. The basic philosophy of virtual instrumentation is the replacement of dedicated hardware with a microprocessor and controlling software, and it was confidently felt that the late Leslie Paddle, a former Vice-President of the Institution, who had bequeathed the funding of the scholarship, would have warmly endorsed the Trustees' choice of this project.‡

Student Award At the request of the South Wales Section, the Executive Committee considered and approved the establishment of a student award in electronics and communications. This calls for papers on these topics from full-time final year students at higher educational establishments in South Wales. Applicants short-listed are required to prepare and present their papers by means of a fifteen-minute summary with visual aids at an open meeting of the Institution and are afterwards required to answer questions about the project from a panel of adjudicators. The successful student will receive a certificate endorsed by the seal of the Institution and a prize of £50; and the award will be dedicated to the memory of the Institution's revered Past President (1967), the late Professor Emrys Williams.

* *The Electronics Engineer*, no. 42, 7th January 1982

† *The Radio and Electronic Engineer*, **51**, no. 7/8, p. 307, July/August 1981.

‡ *The Radio and Electronic Engineer*, **51**, no. 10, p. 467, October 1981.

President's Badge On the appointment of Mr John Powell as President, his company, Cable and Wireless, had indicated its intention to present to the Institution a suitably designed collar badge of office to be worn on appropriate occasions by successive Presidents. Despite the subsequent sad death of John Powell, Cable and Wireless expressed the wish to proceed as originally planned, and the design and production of a Presidential Badge was accordingly put in hand. An officer from Cable and Wireless presented the insignia* to its first holder, the newly elected President, Mr H. E. Drew, at the Annual General Meeting in October 1981.

Overseas Affairs The Institution's support of overseas bodies representing the engineering profession was maintained, and through CEI the interest of the British electronic and radio engineer have been well represented in such as FEANI (Federation of European National Associations of Engineers), CEC (Commonwealth Engineering Conference), IFAC (International Federation of Automatic Control). In addition, the Institution is directly represented at the Convention of National Societies of Electrical Engineers of Western Europe (EUREL) by Brigadier R. W. A. Lonsdale (Fellow), who attended its General Assembly in Paris on 1st October 1981.

Honorary Fellowship The Institution's Clerk Maxwell Memorial Lecture was presented during the Conference on Radio Receivers at the University of Leeds in July 1981 by the well-known physicist, Professor R. V. Jones, C.B., C.B.E., F.R.S., who took as his title—'The Complete Physicist: James Clerk Maxwell 1831–1879'.† This memorial lecture, the tenth in the series, gave a most interesting insight into the life and work of one of the outstanding physicists of the nineteenth century, on whose electromagnetic theory modern radio engineering has been built.

The Executive Committee, spurred by the excellence of the lecture, recommended that Professor R. V. Jones's many achievements should be recognized by inviting him to become an Honorary Fellow of the Institution. Council unanimously agreed and Professor Jones was pleased to accept this, the highest distinction the Institution could bestow.‡

Finance When assessing the implications of last year's financial results, the Executive Committee considered it imperative that this year, being the first of the two-year

* *The Radio and Electronic Engineer*, **52**, no. 1, p. 12, January 1982.

† *The Radio and Electronic Engineer*, **51**, nos. 11/12, p. 527, November/December 1981.

‡ *The Radio and Electronic Engineer*, **52**, no. 7, p. 313, July 1982.

cycle having the benefit of the recent subscription increase, should show a substantial excess of income over expenditure. In the event the interim figures covering the first 8 months of the financial year were, to say the least, disappointing. The total income for the period did little more than reflect the increased return from subscriptions whilst the expenses involved in publishing and printing were higher than the income from these items.

In order to combat this disturbing trend it was decided to embark on an even more stringent programme of economies than had already been put into effect whilst all those concerned with publications sales and symposia redoubled their efforts. The result of these activities was a dramatic upturn in the financial results for the year as a whole: the final figures showing the biggest excess of income over expenditure ever recorded—£74,550.

The total income for the year is over £127,000 higher than last year, less than half of which is the result of increased subscriptions. Income from publications, symposia and colloquia shows an increase of £66,638, and the costs and expenses related to this income are only £27,089 more than last year.

The combined expenses of administration and establishment for 1981/1982 have been held to within 5½% of last year's figure—a considerable achievement in view of the general level of inflation experienced over the same period. Notable amongst these figures is a saving of over £4,000 on bank charges, reflecting tight financial control over the much improved cash flow. The increase of some £5600 in the Divisions and Sections operating expenses is reasonable in view of Council's wish to see an increase in learned society activity in these areas during the year.

By far the most important effect of this year's excellent results is the total elimination of the General Fund deficit which last year stood at over £71,000. Lest, however, members get caught up in euphoria as a result of this year's figures, a note of caution must be expressed. It will be seen that in the income for 1981/2 there is an extraordinary item of £17,768, the bulk of which arose from the excellent response to the Secretary's appeal referred to in the Introduction to this Report. This source of income will not be available in 1982/83.

Whilst every effort will be made to maintain the income from symposia and colloquia it is very doubtful whether it will be possible to do as well in 1982/3 as this year. It is also inevitable that the administration and establishment costs will show a sizeable increase during the coming year when radical changes will have to be made to the HQ staff structure in the context of the work of the new Engineering Council. Nevertheless, the Executive Committee's 1982/83 Budget is aimed at a rather better than break-even target in order to hold the sound balance achieved in this year's accounts—a state that has been so hardly won and which is so important to the Institution's growth and future.

Finally, it is only right that the Executive Committee place on record the thanks and congratulations due to the Secretary, his staff, and all those concerned with the financial well-being of the Institution for their combined efforts towards the end which this year has been achieved.

PROFESSIONAL ACTIVITIES COMMITTEE

Bearing in mind the comments made in this section of last year's report concerning the adverse effects on the Institution's programme of conferences and colloquia resulting from the economic pressures on industry and higher education, it is encouraging to note a marked improvement in this area during the year now under review. The Committee was confident that a programme of conference and colloquia on topics directly relevant to potential delegates' immediate tasks could attract substantial support. The pattern of activities for 1981–82 covered a range of conferences incorporating the traditional three-day conference, one-day and two-day events and a tutorial day consisting of five one-hour lectures in conjunction with the first major conference held in the year under report ('Digital Processing of Signals in Communications'). This pattern has proved to be successful.

During the year the Recording Group held its first colloquium, as did the Information Technology Group which was formed by a merger of the Computer and Microprocessor Group.

Conferences During the year the Institution held five events of its own and participated as primary learned society contributor to one further major event associated with an international exhibition:

'Digital Processing of Signals in Communications' (April 1981, University of Technology, Loughborough) (3 day plus tutorial day)
'Radio Receivers and Associated Systems' (July 1981, University of Leeds) (3 day event)
'Electronics for Ocean Technology' (September 1981, University of Birmingham) (3 day event)
'Industrial Applications of Learning Curves' (December 1981, London) (1 day event—non-residential)
'Fibre Optics' (March 1982, London)
(2 day event—non-residential)

A total of 723 delegates attended these conferences, including 106 who attended the tutorial day organized in conjunction with the 'Digital Processing of Signals in Communications' Conference in April.

An in-house exhibition was associated with the conference on 'Electronics for Ocean Technology' at Birmingham.

The 'Automatic Testing' international exhibition/conference with which the Institution was associated was held at Brighton in December 1981 and attracted over 500 delegates.

The full texts of all the papers presented at these conferences were published as bound volumes and are available on sale from, or through, the Institution's Publications Department.

Colloquia A total of 4 London one-day events were held during the year under report:

'Waveguides and Components for the 80–3000 GHz Range' (April 1981) (Sponsoring Committee—Components and Circuits: Attendance—78)
'Management Projects containing Software' (May 1981) (Sponsoring Committee—Electronics Production Technology: Attendance—65)
'Image Processing for Automatic Inspection and Robotic Vision' (February 1982) (Sponsoring Committee—Information Technology: Attendance—108)
'Digital Techniques in Audio Recording' (February 1982) (Sponsoring Committee—Recording Group: Attendance—133)

The total of 384 delegates represents a substantial improvement on last year and more than justifies the continuation of this facet of the Institution's learned society programme.

Local Section Activities During the period of the report the sixteen Local Sections held 129 meetings, one public exhibition and one evening symposium. The exhibition was arranged by the Scottish Section in conjunction with Ferranti and held in the Appleton Tower, Edinburgh. The symposium took the form of a public forum-type discussion arranged by the South Wales Section as a contribution to 'Information Technology Year'. In addition to their own activities, Section Committees continued to sponsor joint meetings and support the activities of CEI and of kindred Societies and Institutions in their areas.

Local support for Section activities appears to have increased since the last report but some committees, notably East Anglian and Bedfordshire and Hertfordshire, are still concerned about poor attendance at meetings and the difficulty they experience in recruiting committee members.

Two noteworthy changes have occurred in Section administration. Firstly, the members formerly recorded as belonging to the 'London Section' have been transferred to the East Anglian, Kent, Southern, Thames Valley, and Bedfordshire and Hertfordshire Sections. This redistribution was undertaken to ensure that these members would once again receive information on Institution activities; a service which they effectively lost when London meetings were discontinued in 1979. Secondly, a small subsection of the Scottish Section is being formed at Aberdeen. Section administration has been satisfactory.

EDUCATION AND TRAINING COMMITTEE

Accreditation of Courses At the conclusion of last year's Annual Report, the hope was expressed that during the following year decisions would be taken which would end the uncertainty about the future regulation of the engineering profession. Although decisions have now been made, and a British Engineering Council has been established, it will probably be two years at least before the question of how soon and to what extent the new Council will take over the functions of CEI is settled. In the meantime, CEI intends to continue 'business as usual'—but inevitably some of its intended activities have been delayed. In particular, the letter advising UK Universities and Polytechnics of CEI's intention to accredit all engineering degree courses, which the Committee expected would be sent in the early summer of 1981, was not despatched until mid-November. The Institution was in consequence obliged to postpone the commencement of its own accreditation programme, because of uncertainty regarding the action it would be required to take to secure exemption from the CEI examinations for all graduates from degree courses in respect of which the IEE had already indicated its intention to accept only those who secure second-class honours or above.

Although the procedure to be followed was agreed before the end of 1981, the desire not to involve degree-awarding bodies in pointless duplication of paperwork led the Committee to defer commencement of its own accreditation programme until March 1982. Nevertheless, it expects that by the time this Report appears, the working group which it has appointed to study degree of interest to the Institution will have made a number of recommendations to CEI and that among these there will have been some in respect of degrees in the fringe disciplines with a significant electronic engineering content, which Council has particularly asked should be considered. It was with particular regret that the Committee learned that Mr B. F. Gray, a past Chairman and loyal member for many years, had died before the first meeting of this working group, on which he had agreed to represent the Polytechnic interest.

Technician Engineer Qualifications Since Mr Gray was also one of the Institution's three representatives on the Joint Committee for HNC's and HND's in Electrical/Electronic engineering, this would seem an appropriate point to record the fact that the days of the HND are numbered. Early in its 1981/82 session the Committee learned with great concern that it had been suggested that the HND's in Electrical/Electronic Engineering and Mechanical/Production Engineering might be replaced by the New 'Route I' degrees proposed at the Trent Conference. These degrees would differ from the usual engineering degree pattern by requiring only two non-specific 'A' levels as a condition of entry. It was agreed to support the Institution's representatives on the Joint Committee if they decided to withdraw rather than accept the proposal. Fortunately, the need did not arise: instead the Department of Education placed upon the TEC the responsibility of devising an acceptable replacement for the HND. While final agreement on some points has yet to be reached, the latest TEC proposals go some way towards meeting the Joint Committee's requirement, although agreement has still to be reached on a final scheme. Nevertheless it is likely that the last intake to HND courses in the present form could be that of September 1983.

It is not only the Joint Committee front that the proponents of a 'B.Tech' for Technician Engineers have met strong opposition. At the end of 1981 Sir Kenneth Corfield (Chairman of the new British Engineering Council) sent to interested parties a questionnaire in which he sought their views on various recommendations made in the report of the National Conference on Engineering Education and Training. The Education Committee, replying on behalf of the Institution, expressed total disagreement with the 'B.Tech' proposal contained in the Report and was pleased to learn later that CEI's Standing Committee 'A' and the Electrical and Electronic Manufacturers' Training and Education Board had taken a similar stand. All are agreed on the need for a Technician Engineer award suitable for the 'A' level holder who cannot or does not aspire to eventual Chartered Engineer status, but insist that it must not be a debased degree. Similarly, the Committee was pleased to note that both the bodies named shared its view that recommendations regarding engineering degrees quoted in the questionnaire leaned too far towards the M.Eng. proposed by Finniston (and rejected by the Conference) and made inadequate provision for the engineering undergraduate of average ability.

The CEI Examination At its meetings in September and November 1981 the Committee undertook its customary review of the performance of IERE-sponsored candidates in the year's CEI examinations and comparison with that of those in other disciplines. The number of candidates sponsored by the Institution continues to rise. Part 1 entries totalled 124 and Part 2 entries (including those granted partial exemption) 506. Of these 14 passed Part 1, and 115 passed Part 2 or the prescribed number of Part 2 subjects to meet the academic requirements for Graduate or Corporate membership of the Institution. The Committee was pleased to note the considerably increased percentage of passes in the 'bogey' Part 2 subject 'The Engineer in Society' and to learn that CEI's Chartered Engineer Section Board had accepted its recommendation that indefinite referment should be permitted in this subject. It continued, however, to be concerned about candidates' poor performances in three Part 1 subjects—201 (Mathematics), 202 (Mechanics) and 203 (Properties of Materials) and has asked the few Colleges which offer courses of preparation for the examination to investigate the possibility of devoting more time to these subjects. Because of other commitments, it was not possible to proceed further with assessment of TEC Higher Certificates/Diplomas either as Technician Engineer qualifications or in the context of possible exemption from Part 1 of the CEI examination, but the Committee has maintained close contact with those CEI/ERB Committees which are also considering the problem.

Training Regulations Where the training aspect of its duties is concerned, the Committee was pleased to learn in January 1982 that its revised Training Regulations have been approved by CEI. By the time this Report appears these will have been incorporated in the Membership Regulations and Training Summary forms will be available to assist trainees in recording, and the Institution in assessing, the receipt of satisfactory training. A working group appointed by the Committee has already approved a number of company training schemes which had been held in abeyance pending CEI approval of the Training Regulations, but there is still much work to be done in respect of monitoring the training of those who do not follow approved schemes and/or receive training overseas. It is hoped that the Institution's Hong Kong Section will be able to undertake a supervisory role in respect of training received in that area.

Future Activities of the Committee The Committee continues to believe that present conditions are not favourable to the mounting of a substantial Conference on educational topics and because of the poor support generally given to smaller events has not made any recommendations for the latter to Council. It hopes, however, that the time will soon come when it can resume activity in a field of such concern to the Committee, and especially its retiring Chairman, Mr D. L. A. Smith. Mr Smith, who has occupied the chair since the end of 1972, expressed a wish to retire a year ago, but was urged, because of the general uncertainty prevailing in the educational world, to preside over one more session. By the time these words appear that session will have ended: it is fitting, therefore, that this Report should conclude by wishing him well, hoping he will continue to serve as an ordinary member, and welcoming his successor, Dr F. Goodall.

MEMBERSHIP COMMITTEE

The Membership Committee met on only ten occasions during the year under report: the other two routine monthly meetings having to be cancelled for administrative reasons. Despite this, however, the Committee considered more membership proposals than in any of the last seven years bar one. Of these proposals, 530 were for direct election, 204 for transfer and 67 for reinstatement. At the close of the year a further 178 proposals were being processed for the Committee's consideration, this procedure having been further complicated this year by the need to establish with particular care the standing of all candidates in relation to the Institution's (CEI's) more formalized training requirements.

The strength of the Institution's membership at the close of the year is summarized in our customary manner

Table 1. Institution Membership April 1981 to March 1982

	Membership at 1st April 1981	ADDITIONS				DEDUCTIONS						Membership at 31st March 1982
		Direct Elections	Reinstatements	Transfers	Total Additions	Removals	Deaths	Resignations	Transfers	Total Deductions	Nett Gain (+) or Loss (−)	
Honorary Fellows	10	1	—	—	1	—	—	—	—	—	+1	11
Fellows	766	5	2	24	31	4	10	2	—	16	+15	781
Members	7408	95	38	68	201	88	26	38	24	176	+25	7433
Total Corporate Membership	**8184**	**101**	**40**	**92**	**233**	**92**	**36**	**40**	**24**	**192**	**+41**	**8225**
Graduates	2541	93	13	83	189	76	2	41	61	180	+9	2550
Companions	18	—	—	—	—	—	—	—	—	—	—	18
Associates	311	3	3	—	6	12	4	9	3	28	−22	289
Associate Members	1033	78	9	17	104	38	4	9	14	65	+39	1072
Students	1346	253	2	—	255	164	1	17	90	272	−17	1329
Total Non-Corporate Membership	**5249**	**427**	**27**	**100**	**554**	**290**	**11**	**76**	**168**	**545**	**+9**	**5258**
Grand Total	**13433**	**528**	**67**	**192**	**787**	**382**	**47**	**116**	**192**	**737**	**+50**	**13483**

in Table 1. From this it can be seen that whilst the net gain on the year was only 50, the professionally qualified membership strength, i.e. Fellows, Members and Associate Members, continued to grow in a very healthy manner. Particularly noteworthy in this context is the addition of 104 new Associate Members—an indication of the trend which is confidently expected to develop from the Council's decision to seek Privy Council authority for this grade of member to use IERE designatory letters once again.

Annual Reports of the Membership Committee in recent years have usually commented adversely on the continuing loss of long-standing Graduate members due to the discouraging effect of the CEI rules introduced in 1974. In 1980–81, for example, the actual loss of Graduate members was shown as 230, and in 1976–77, the worst of the last five years in this regard, it was 500. It is, therefore, especially gratifying for the Committee to be able to report a net increase in our Graduate membership strength for the first time in many years, a development which is seen as a very promising sign for the future. The only other comment that need be made on the membership state presented in Table 1 is that applications for the customary annual intake of overseas Student members did not come to hand by the end of the year so could not be included in the Table: hence the most unusual net loss report for this class of member.

No new initiatives to increase membership were taken during 1981–82, the Committee preferring to await the outcome of the Council's application for Royal Charter and Bye-law amendments to improve the position of Associate Members and the announcement of the Engineering Council's registration standards before devoting any further IERE resources to this end.

PAPERS COMMITTEE

Throughout the year the aim of the Papers Committee has been to publish papers in *The Radio and Electronic Engineer* which cover as much as is practicable of the great range of subjects with which the electronics engineer is concerned today. Thus papers have appeared on subjects as diverse as Combinational logic design, Viewdata, Magnetic bubble memories, Man-pack satellite communications earth station, Solar cells, Automatic gain control theory and Hexagonal ferrite radar absorbers. During the year, the April and July/August issues had particular themes: in the earlier issue the subject of Radio and Radar Ignition Hazards was featured while in the double issue of July/August ten papers dealing with important aspects of Optical Fibre Communications were assembled under the guest editorship of Mr C. J. Lilly. The practice of devoting a greater part of a particular issue to a special subject has been followed now for some ten years, such feature issues being published two or three times in each year, collections of a balanced group of papers covering the 'state-of-the-art' having convenient reference value. The aim has always been to maintain a balance between theory and practice over the year and even if possible within individual issues. At the end of the year under review, planning was well advanced for issues during the latter part of 1982 on *UOSAT* (the University of Surrey Satellite) and on Millimetric Waves.

As in previous years the Papers Committee has selected, with the co-operation of the organizing committees concerned, papers from IERE conferences which have particular significance in their own right or which, with other papers from the conference, provide an overview of the conference proceedings.

The international circulation of *The Radio and Electronic Engineer* has always attracted papers by radio and electronic engineers from all over the world and it is interesting to note that in Volume 51 there were authors from Greece, Hong Kong, India, Iraq, the United States and Yugoslavia.

Reference was made in last year's Annual Report to the Committee's decision to visit centres of research. In November 1981 by kind permission of the head of department, Professor B. McA. Sayers, and with the co-operation of Professor J. C. Anderson (a former member of the Committee), a visit was made to the Department of Electrical Engineering at Imperial College. A number of most interesting items from the Department's wide range of research activities were seen and it is hoped that in due course papers will appear in the IERE's Journal describing some of these. It is pleasing to record that three papers have been published as a direct result of the visit in June 1980 to the Electronic and Electrical Engineering Department of University College London.

Assessment of Papers The total number of papers assessed during the year, which includes conference papers recommended by the respective organizing committees for consideration for publication, was as follows (1980/81 figures being given in parentheses):

Number of papers considered	147	(136)
Accepted for publication	65	(56)
Returned for revision	12	(24)
Rejected	70	(56)

The Committee believes it is in the interests of Journal readers that it should continue to set a high standard for papers. The rejection rates are comparable both for papers submitted directly for publication and those being considered for reprinting from Conference Proceedings.

Premiums Twelve of the 20 Institution Premiums annually available for award are to be presented for outstanding papers published in the Journal during 1981. It is interesting to note that the authors of six of the papers were from industry (one a US company), three from universities and three from government or similar organizations. Details are given in Appendix 8.

INSTITUTION PUBLICATIONS

The Radio and Electronic Engineer The overall size of the 1981 volume of *The Radio and Electronic Engineer* was exactly the same as its predecessor, namely 630 pages, and this represented a high proportion of pages of papers: the majority of announcements and all meetings notices are now published in the fortnightly newspaper, *The Electronics Engineer*, the balance of each issue being normally made up with matter for record and with brief technical news items.

Increased costs right across the board have made it impossible to do more than maintain the physical size of the Journal, the alternative of reducing quality having been rightly rejected. As a result of most helpful discussions with the Institution's printer, a new method of assessing costs has been arrived at which had its impact in the closing months of the financial year and will be a most welcome contribution to offsetting other increases during the next financial year.

Reference was made last year to the hope that through its membership of the Association of Learned and Professional Society Publishers the Institution would be able to help in seeking some easement on postage rates but there has sadly been no real progress in this direction. The adoption of lighter text paper and wrappers is therefore being explored to reduce weight and make the most of the contracts with the Post Office for United Kingdom and Overseas postings.

The circulation of the Journal for the calendar year January to December 1981 shows a small fall on the previous year's figure and now stands at 13,393. The impact of costs worldwide, which has been experienced by all publishers, has made it possible to maintain the numbers of subscribers only by approaching organizations in every area of technology and science making use of electronic techniques, and which therefore may find the Journal a useful source of information on latest developments.

It continues to prove virtually impossible to obtain displayed advertising of products but a number of advertisers have taken advantage of the facility which the Journal affords for bringing their products or services to the notice of members by means of inserted leaflets.

The Electronics Engineer. The fortnightly newspaper, published for the Institution and the Society of Electronic and Radio Technicians by an outside publishing house, has appeared throughout the year and represents an excellent and economic means of providing members with information on forthcoming events such as local section meetings and giving news of industrial and commercial developments.

The amount of editorial content in *The Electronics Engineer* depends to an important extent on the number of pages of advertisements for appointments and services which is obtained. In the light of the current levels of unemployment which affect much of the electronics industry, it is encouraging to note that the number of eight-page issues was exceeding the number of four-page issues towards the end of the year.

Conference Publications Between April 1981 and March 1982 four Conference Publications were produced, namely 'Radio Receivers and Associated Systems', 'Electronics for Ocean Technology', 'Industrial Applications of Learning Curves' and 'Fibre Optics'. (A fifth volume, 'Video and Data Recording' was in production at the end of the year for the conference in April.) The total number of pages for the 96 papers contained in the four volumes was 1193. Following each of these conferences, there have been sales of the volumes of papers throughout the world, in addition to those included in the registration fees and the growing number of advance orders, many of them 'standing orders'.

LIBRARY AND INFORMATION SERVICES

The Institution's Library has continued during the year to provide services to members by the loan of text books, the provision of reprints of papers, and the compilation of lists of references on particular areas of electronics and radio engineering. In the first two of these functions, it draws from time to time on the resources of the British Library and of other engineering institutions, the latter being frequently reciprocated.

The ability to deal with enquiries for information depends not only on the availability of 'in-house' material but also on the ability of the Librarian to use it to the fullest effect; in this last connection assistance can always be most easily and effectively given if the problems are specified in the fullest and clearest terms.

The emphasis in acquisition of books has been influenced by an assessment of the potential future use of a particular title. Several donations of books and runs of journals have been received during the year.

The continuation of subscriptions to journals is a matter of very careful consideration; with inevitably increasing subscription rates the decision has sometimes been to rely for the future on photocopies from other libraries in the case of the less frequently used titles, albeit that these must often imply rather less speedy response than if complete files of a journal can be maintained in the Library.

ACKNOWLEDGMENTS

At a time when so much of society is obsessed by the philosophy of 'what's in it for me', it is important to reiterate that learned bodies depend for their success on the general support of their membership and, more particularly, on the active participation of those members who give their time and expertise to Institution committees, working parties and external representative duties. The IERE is no exception to this rule and Council is especially pleased to acknowledge the high level of this support that has been sustained throughout this most difficult year of recession and industrial uncertainty. To all those members who so ably and willingly contribute to the life and work of the IERE, Council extends its grateful thanks. Council also wishes to pay particular tribute this year to the loyalty and painstaking stewardship exercised by the Secretariat whose efforts have brought the IERE back to a thoroughly sound financial base in time for the new responsibilities which face us in the immediate future with the advent of the Engineering Council and, hopefully, the sustained upturn in national economic activity.

Appendix 1

Membership of the Council and its Committees at the end of the year 1981/82

COUNCIL OF THE INSTITUTION

President:

H. E. Drew, C.B., Hon. C.G.I.A. (*Fellow*)

Past Presidents:

Professor W. A. Gambling, D.Sc., Ph.D., F.Eng. (*Fellow*)
D. W. Heightman (*Fellow*)
Professor W. Gosling, D.Sc., B.Sc. (*Fellow*)

Vice-Presidents:

Colonel W. Barker (*Fellow*)
L. A. Bonvini (*Fellow*)
Professor J. R. James, B.Sc., Ph.D., D.Sc. (*Fellow*)
P. K. Patwardhan, M.Sc., Ph.D. (*Fellow*)
Major-General H. E. Roper, C.B., B.Sc.(Eng.) (*Fellow*)
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)
Group Captain J. M. Walker, RAF (*Fellow*)

Ordinary and ex-officio Members:

P. Atkinson, B.Sc. (*Member*)
L. W. Barclay, B.Sc. (*Fellow*)
P. V. Betts (*Member*)*
W. R. Crooks, B.A. (*Member*)*
I. D. Dodd, B.Sc. (*Member*)*
B. F. Gray, B.Sc., A.C.G.I. (*Fellow*)*
D. J. Houliston (*Member*)*
P. J. Hulse (*Associate Member*)
Lt Cdr C. J. Jackson, B.A., RN (Ret.) (*Member*)*
J. J. Jarrett (*Member*)
D. J. Kenner, B.Sc., M.Sc. (*Member*)
R. Larry (*Fellow*)
P. W. Lee (*Member*)*
W. G. McConville (*Member*)*
G. A. McKenzie, B.Sc. (*Fellow*)
V. A. J. Maller, M.A. (*Fellow*)
B. Mann, M.Sc. (*Fellow*)†
R. B. Michaelson (*Companion*)
C. L. Munday (*Member*)*
Professor K. G. Nichols, B.Sc., M.Sc. (*Fellow*)
B. J. Stanier (*Member*)*
K. R. Thrower (*Member*)†
Professor R. A. Waldron, M.A., Sc.D. (*Fellow*)*
L. Walton (*Member*)*
T. Whiteside (*Member*)*
A. Williams, B.Sc (*Member*)*
M. W. Wright (*Associate*)

Honorary Treasurer:

S. R. Wilkins (*Fellow*)

Secretary:

Sinclair M. Davidson, C.B.E. (*Fellow*)

* *Chairman of a Local Section in the UK*
† *Ordinary member of the Council who is also a Chairman of a Local Section*

STANDING COMMITTEES OF THE COUNCIL

Executive Committee

Chairman:
H. E. Drew, C.B., C.G.I.A. (*Fellow*)

Colonel W. Barker (*Fellow*)
L. A. Bonvini (*Fellow*)
Professor W. Gosling, D.Sc., B.Sc. (*Fellow*)
D. W. Heightman (*Fellow*)
Professor J. R. James, B.Sc., Ph.D., D.Sc. (*Fellow*)
R. Larry (*Fellow*)
Professor K. G. Nichols, B.Sc., M.Sc. (*Fellow*)
Major-General H. E. Roper, C.B. (*Fellow*)
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)
Group Captain J. M. Walker, RAF (*Fellow*)
S. R. Wilkins (*Fellow*)

Education and Training Committee

Chairman:
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)

K. J. Coppin, B.Sc. (*Member*)
Commander A. H. C. Fraser, B.Sc.(Eng.), RN (*Fellow*)
P. J. Gallagher, M.Sc., Ph.D. (*Member*)
F. Goodall, B.Sc., Ph.D. (*Member*)
B. F. Gray, B.Sc. (*Fellow*)
R. W. S. Hewitt (*Fellow*)
G. P. Heywood, B.Sc. (*Graduate*)
C. H. G. Jones (*Member*)
A. J. Kenward, B.Sc. (*Member*)
P. J. Morley (*Member*)
Professor K. G. Nichols, B.Sc., M.Sc. (*Fellow*)
W. L. Price, O.B.E., M.Sc., Ph.D. (*Fellow*)
A. C. Shotton (*Fellow*)
Squadron Leader P. Walters, RAF (*Member*)
Lieutenant-Colonel S. T. Webber, REME (*Member*)

Membership Committee

Chairman:
Wing Commander P. J. Dunlop, RAF (Ret.) (*Fellow*)

C. W. Brown, M.A. (*Member*)
D. A. Burgess (*Member*)
R. M. Clark (*Member*)
Commander A. C. Cowin, RN (*Member*)
A. N. Heightman (*Fellow*)
H. Hudson (*Member*)
Brigadier R. W. A. Lonsdale, C.B.E., B.Sc. (*Fellow*)
Lieutenant Colonel A. R. Lyon, REME (*Member*)
J. W. Morris (*Member*)
D. G. Roberts (*Member*)
R. S. Roberts (*Fellow*)
W. R. Seymour (*Member*)
J. B. Stephens (*Member*)
Group Captain J. M. Walker, RAF (*Fellow*)
M. M. Zepler, M.A., Dip.El. (*Member*)

Professional Activities Committee

Chairman:
Brigadier R. Knowles, C.B.E. (*Fellow*)

Colonel W. Barker (*Fellow*)
K. Copeland (*Member*)
A. F. Dyson, Dip.El. (*Member*)
Professor P. B. Fellgett, M.A., Ph.D. (*Fellow*)
A. Hann, B.Sc. (*Fellow*)
Commander D. J. Kenner, B.Sc., M.Sc. (*Member*)
R. Larry (*Fellow*)
Professor K. G. Nichols, B.Sc., M.Sc. (*Fellow*)
Professor P. A. Payne, Ph.D. (*Member*)
C. O. Peck (*Member*)
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)
J. K. Stevenson, B.Sc., Ph.D. (*Member*)
Professor D. R. Towill, D.Sc., M.Sc. (*Fellow*)
W. E. Willison (*Fellow*)
M. M. Zepler, M.A., Dip. El. (*Member*)

Papers Committee

Chairman:
L. W. Barclay, B.Sc. (*Fellow*)

K. F. Baker, M.Sc. (*Member*)
Professor J. D. E. Beynon, M.Sc., Ph.D. (*Fellow*)
L. A. Bonvini (*Fellow*)
W. G. Burrows, Ph.D., D.I.C. (*Member*)
M. P. Circuit, Dip. El., B.Sc. (*Member*)
R. J. Cox, B.Sc. (*Member*)
A. B. E. Ellis (*Fellow*)
K. G. Freeman, B.Sc. (*Member*)
A. E. Hilling (*Member*)
R. M. B. Jackson (*Member*)
G. G. Johnstone, B.Sc. (*Member*)
C. J. Lilly (*Member*)
E. Robinson, B.Sc., Ph.D. (*Fellow*)
A. G. Wray, M.A. (*Fellow*)

Trustees of the Institution's Benevolent Fund

H. E. Drew, C.B., Hon. C.G.I.A. (*Fellow*) President
S. R. Wilkins (*Fellow*) Hon. Treasurer
S. M. Davidson, C.B.E., (*Fellow*) Secretary

SPECIALIZED GROUP COMMITTEES

Aerospace, Maritime and Military Systems Committee

Chairman:
A. Hann, B.Sc. (*Fellow*)

N. G. V. Anslow (*Member*)
Colonel W. Barker (*Fellow*)
Brigadier P. A. Dally, C.B.E. (*Member*)
P. R. Hopkin (*Member*)
J. A. C. Kinnear (*Fellow*)
R. N. Lord, M.A. (*Member*)
R. B. Mitson, M.Sc. (*Member*)
C. H. Nicholson (*Fellow*)
Commander A. R. B. Norris, RN (Ret.) (*Associate Member*)
R. M. Trim, O.B.E. (*Fellow*)

Automation and Control Systems Group Committee

Chairman:
Commander D. J. Kenner, B.Sc., M.Sc. (*Member*)

Lieutenant Commander M. J. Ashworth, B.Sc., Ph.D. (*Member*)
P. Atkinson, B.Sc.(Eng.), A.C.G.I. (*Member*)
R. L. Davey, B.Sc., Ph.D. (*Member*)
C. Foxwell, B.Sc. (*Member*)
W. F. Hilton, D.Sc. (*Fellow*)
M. Kinsey (*Member*)
Brigadier R. Knowles, C.B.E. (*Fellow*)
B. Mann, M.Sc. (*Member*)
J. L. Paterson, M.B.E. (*Member*)
Professor D. R. Towill, D.Sc., M.Sc. (*Fellow*)
Group Captain J. M. Walker, RAF (*Fellow*)
Professor D. R. Wilson, B.Sc., Ph.D. (*Fellow*)

Communications Group Committee

Chairman:
M. M. Zepler, M.A., Dip.El. (*Member*)

A. R. Bailey, M.Sc., Ph.D. (*Fellow*)
L. W. Barclay, B.Sc. (*Fellow*)
A. P. Clark, M.A., Ph.D. (*Member*)
L. W. Germany, (*Fellow*)
F. Goodall, M.Sc., Ph.D. (*Member*)
A. N. Heightman (*Fellow*)
J. J. Jarrett (*Member*)
G. R. Jessop (*Member*)
A. A. Kay (*Fellow*)
R. Larry (*Fellow*)
G. A. McKenzie, B.Sc. (*Fellow*)
P. L. Mothersole (*Fellow*)
R. S. Roberts (*Fellow*)
K. R. Thrower (*Member*)
K. E. Ward (*Member*)
D. Wilkinson (*Fellow*)

Components and Circuits Group Committee

Chairman:
J. K. Stevenson, B.Sc., Ph.D. (*Member*)

K. F. Baker, M.Sc. (*Member*)
C. R. Caine, B.Sc. (*Member*)
R. C. French, B.Sc., Ph.D. (*Fellow*)
B. V. Northall, C.G.I.A. (*Member*)
C. J. Radcliffe, M.Sc. (*Co-opted*)

Electronics Production Technology Group Committee

Chairman:
L. Hale (*Member*)

R. Bavister (*Co-opted*)
J. F. Burns (*Member*)
A. F. Dyson, Dip. El. (*Fellow*)
R. W. Hill (*Fellow*)
D. G. Horan, B.A. (*Member*)
R. P. Marie (*Member*)
Professor D. R. Towill, D.Sc., M.Sc. (*Fellow*)

Information Technology Group Committee

Chairman:
Professor K. G. Nichols, B.Sc., M.Sc. (*Fellow*)

Colonel W. Barker (*Fellow*)
M. S. Birkin, T.D. (*Fellow*)
C. E. Dixon, B.A. (*Member*)
D. B. Everett, B.Sc., Ph.D. (*Member*)
P. L. Hawkes, B.Sc. (*Member*)
D. G. Horan, B.A. (*Member*)
D. T. Law (*Member*)
Professor D. W. Lewin, M.Sc., D.Sc. (*Fellow*)
V. A. J. Maller, M.A. (*Fellow*)
R. B. Michaelson (*Companion*)
M. A. Perry, M.Sc. (*Fellow*)
E. R. Tomlinson (*Member*)
D. E. O'N. Waddington (*Fellow*)

Measurements and Instruments Group Committee

Chairman:
Professor P. A. Payne, Ph.D. (*Member*)

A. E. Drake (*Co-opted*)
W. A. Evans, B.Sc., M.Sc. (*Fellow*)
Professor P. B. Fellgett, M.A., Ph.D. (*Fellow*)
E. P. Fowler, M.A. (*Co-opted*)
M. H. W. Gall, M.A. (*Fellow*)
R.F F. Monger (*Member*)
J. K. Murray (*Associate*)
D. E. O'N. Waddington (*Fellow*)
P. C. F. Wolfendale (*Fellow*)

Medical and Biological Electronics Group Committee

Chairman:
K. Copeland (*Member*)

J. S. Armour (*Member*)
R. Brennand (*Member*)
A. E. Hay, M.Phil. (*Member*)
Professor P. A. Payne, Ph.D. (*Member*)
L. W. Price, M.A. (*Member*)
J. R. Roberts, B.Sc., Ph.D. (*Member*)
H. J. Terry, B.A., Ph.D. (*Member*)

Recording Group Committee

Chairman:
Colonel W. Barker (*Fellow*)

A. J. Collins, Ph.D. (*Member*)
A. V. Davies, B.Sc., M.Sc. (*Fellow*)
H. D. Ford (*Member*)
A. N. Heightman (*Fellow*)
M. J. Humphries (*Member*)
R. Larry (*Fellow*)
B. K. Middleton, B.Sc., Ph.D. (*Member*)
B. V. Northall, C.G.I.A. (*Member*)
M. A. Perry, M.Sc. (*Fellow*)
C. E. Urban (*Graduate*)
G. White, C.G.I.A. (*Member*)

Appendix 2

Representatives of the Institution on the Board and Committees of the Council of Engineering Institutions

Board of CEI
H. E. Drew, C.B., Hon.C.G.I.A. (*Fellow*)
D. W. Heightman (*Fellow*)

Executive Committee
Professor W. Gosling, D.Sc., B.Sc. (*Fellow*)

Standing Committee B (Internal Affairs)
Brigadier R. W. A. Lonsdale, C.B.E., B.Sc. (*Fellow*)

Standing Committee C (Home Affairs)
Professor J. R. James, B.Sc., Ph.D., D.Sc. (*Fellow*)

Standing Committee D (Regional Affairs)
A. S. Prior (*Member*) (Kent Section)

Standing Committee F (Technical Affairs)
Colonel F. R. Spragg, B.Sc. (*Fellow*)

CES—CSTI Joint Affairs Committee
To be appointed

Council for Environmental Science and Engineering
Professor H. M. Barlow, Ph.D., F.R.S., F.Eng. (*Honorary Fellow*)

British National Committee on Ocean Engineering
M. J. Tucker, B.Sc. (*Member*)

Committee on Health and Safety
Colonel F. R. Spragg, B.Sc. (*Fellow*)

Engineers Registration Board:
Chartered Engineers Section Board
Group Captain J. M. Walker, RAF (*Fellow*)
Educational Qualifications Committee
K. J. Coppin, B.Sc. (*Member*)

Committee on Training and Experience
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)

Technician Engineer Section Board and Supervisory Committee
K. J. Coppin, B.Sc. (*Member*)

Joint Qualifications Committee
Brigadier R. W. A. Lonsdale, C.B.E., B.Sc. (*Fellow*) (Chairman)

Appendix 3

Institution Representation at Universities, Polytechnics and Colleges

University of Aston in Birmingham
Convocation
Professor D. G. Tucker, D.Sc., Ph.D. (*Fellow*)

University of Bradford
Court
P. J. Gallagher, M.Sc., Ph.D. (*Member*)

Cranfield Institute of Technology
Court
W. L. Price, O.B.E., M.Sc., Ph.D. (*Fellow*)

University of Nottingham
Court
Air Vice-Marshal S. M. Davidson, C.B.E. (*Fellow*)

University of Surrey
Court
Professor W. Gosling, D.Sc., B.Sc. (*Fellow*)

University of Wales Institute of Science and Technology
Court
V. J. Phillips, Ph.D., B.Sc. (*Member*)

Barnsley College of Technology
Engineering Advisory Committee
To be appointed

Darlington College of Technology
Electrical Engineering and Science Advisory Committee
R. W. Blouet (*Member*)

East Ham Technical College
Electrical Engineering Advisory Committee
D. W. Bradfield, B.Sc. (*Member*)

Glasgow College of Technology
Advisory Board
R. D. Pittilo, B.Sc. (*Member*)

City of Gloucester College of Technology
Electrical Engineering Advisory Committee
H. V. Sims (*Fellow*)

Huddersfield Technical College
Engineering Advisory Committee
R. Barnes (*Member*)

Merton Technical College
Board of Governors
A. A. Kay (*Fellow*)

City of Nottingham Education Committee
Electrical Engineering Advisory Committee
F. W. Hopwood (*Member*)

Reading College of Technology
Board of Governors
Major-General Sir Leonard Atkinson, K.B.E., B.Sc. (*Fellow*)

Southall College of Technology
Governing Body
B. S. Pover (*Member*)

South East London College
Engineering Consultative Committee
J. I. Collings (*Fellow*)

Stannington College of Further Education, Sheffield
Electrical and Telecommunications Consultative Committee
P. A. Bennett (*Fellow*)

Wakefield College of Technology and Arts
Engineering Advisory Committee
M. Holroyd, M.Sc. (*Member*)

Watford College of Technology
Engineering Advisory Committee
F. P. Thomson, O.B.E. (*Member*)

Widnes Technical College
Electrical and Instrument Engineering Advisory Committee
D. Chalmers (*Fellow*)

Appendix 4

Representatives on Joint Committees for the Awards of National Certificates and Diplomas in Engineering

England and Wales

Higher National Certificates and Diplomas in Electrical and Electronic Engineering:
B. F. Gray, B.Sc. (*Fellow*) Chairman
D. L. A. Smith, B.Sc.(Eng.) (*Member*)
A. Tranter, B.Sc. (*Member*)

Scotland

National Certificates in Electrical and Electronic Engineering:
D. S. Gordon, Ph.D., B.Sc. (*Member*)
D. Dick, D.I.C. (*Fellow*)

Northern Ireland

Higher National Certificates in Electrical and Electronic Engineering:
Captain A. W. Allen, RN (Ret.) (*Member*)
J. A. C. Craig, B.Sc. (*Member*)

Appendix 5

Institution Representation on other Educational Bodies

City and Guilds of London Institute

Telecommunication Advisory Committee
B. F. Gray, B.Sc. (*Fellow*)

Joint Advisory Committee for Radio, Television and Electronics
W. B. K. Ellis, B.Sc. (*Member*)

Radio Amateur Examination Advisory Committee
D. M. Pratt (*Member*)

Advisory Committee on Communication of Technical Information
F. P. Thomson, O.B.E. (*Member*)

Council for National Academic Awards

Electrical and Electronic Engineering Board
C. S. den Brinker, M.Sc. (*Fellow*)

London and Home Counties Regional Advisory Council for Technological Education

Advisory Committee on Electrical and Electronic Engineering
K. J. Coppin, B.Sc. (*Member*)

Scottish Technical Education Council (ScoTEC) Course Committee A2
P. G. Wilks, B.Sc. (*Member*)

Technician Education Council (TEC)

Programme Committee A2
K. R. Thrower (*Member*)

North Western Advisory Council for Further Education

Specialist Advisory Committee for National Education
A. G. Brown (*Member*)

Radio Television and Electronics Examination Board

Air Vice-Marshal S. M. Davidson, C.B.E. (*Fellow*)
W. B. K. Ellis, B.Sc. (*Member*)
N. G. Green (*Member*)

Welsh Joint Education Committee

Electrical and Electronic Engineering Courses Sub-Committee
R. Murray Shelley, B.Sc., M.Sc., Ph.D. (*Fellow*)

West Midlands Advisory Council for Further Education

M. D. Cross, B.A. (*Member*)

Yorkshire Council for Further Education

Engineering County Advisory Committee
F. O. M. Bennewitz, M.Sc. (*Member*)

Appendix 6

Members Appointed to Represent the Institution on External Bodies

EUREL (Convention of National Societies of Electrical Engineers of Western Europe)

Brigadier R. W. A. Lonsdale, C.B.E., B.Sc. (*Fellow*)

British National Council for Non-Destructive Testing

A. Nemet, Dr. Ing. (*Fellow*)

British Nuclear Energy Society

R. J. Cox, B.Sc. (*Member*)

International Broadcasting Convention

Management Committee
P. L. Mothersole (*Fellow*)
R. S. Roberts (*Fellow*)
J. D. Tucker (*Fellow*) Chairman

Programme Committee
P. L. Mothersole (*Fellow*)
R. S. Roberts (*Fellow*)

National Council for Quality and Reliability

Brigadier R. Knowles, C.B.E. (*Fellow*)

National Electronics Council

Professor W. Gosling, D.Sc., B.Sc. (*Fellow*)

Parliamentary and Scientific Committee

P. A. Allaway, C.B.E., D.Tech., F.Eng. (*Fellow*)
Air Vice-Marshal S. M. Davidson, C.B.E. (*Fellow*)

British Electrotechnical Approvals Board

R. S. Roberts (*Fellow*)

Association of Learned and Professional Society Publishers

F. W. Sharp (*Fellow*)

UK Automatic Control Council

P. Atkinson, B.Sc., A.C.G.I. (*Member*)
Colonel W. Barker (*Fellow*)
Professor D. R. Towill, D.Sc., M.Sc. (*Fellow*)

UK Liaison Committee for Sciences Allied to Medicine and Biology

J. R. Roberts, B.Sc., Ph.D. (*Member*)

Watt Committee on Energy

M. S. Birkin, T.D. (*Member*)

Appendix 7

British Standards Institution Representatives

ECL/– Electronic Components Standards Committee

Brigadier R. Knowles, C.B.E. (*Fellow*)

ECL/5 Electronic Tubes

G. R. Jessop (*Member*)

ECL/5/2 Electronic Tube Performance General

G. R. Jessop (*Member*)

ECL/5/8 Electro-Optical Devices

Professor A. Pugh, B.Sc., Ph.D. (*Fellow*)

ECL/11 Piezo-Electric Devices for Frequency Control and Selection

E. Kentley (*Fellow*)

ECL/12/5 Microwave Semiconductor Devices

R. R. Harman (*Member*)

ECL/12/6 Diodes, Transistors and Related Semiconductor Devices

G. Hennessey (*Member*)

EEL/– Electronic Equipment Standards Committee

Brigadier R. Knowles, C.B.E. (*Fellow*)

EEL/8 Electronic Measuring Instruments and Associated Equipment

D. M. Styles (*Member*)

EEL/8/7 Electronic Instruments for Voltage Measurement

D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)

EEL/8/8 Oscilloscopes

D. M. Styles (*Member*)

EEL/23 Radio-Frequency Radiation-Induced Ignition and Detonation

Colonel F. R. Spragg, B.Sc. (*Fellow*)
D. M. Field (*Member*)

EEL/24 Electro-Acoustics

S. Kelly (*Fellow*)

EEL/24/1 Audio Engineering

S. Kelly (*Fellow*)
R. S. Roberts (*Fellow*)

EEL/24/2 Measuring Devices

W. V. Richings (*Fellow*)

EEL/24/3 Ultrasonic Equipment

W. V. Richings (*Fellow*)

EEL/24/4 Performance of High-Fidelity Audio Equipment

R. S. Roberts (*Fellow*)

EEL/25 Radio Communication

R. Larry (*Fellow*)

EEL/25/1 Radio Receiving Equipment

R. S. Roberts (*Fellow*)

EEL/25/4 Aerials

C. Hale (*Fellow*)

EEL/25/7 Wired Distribution Systems

P. Scadeng (*Fellow*)

EEL/25/8 Reception of Sound and Television Broadcasting

P. Scadeng (*Fellow*)

EPC/1 Acoustics

W. V. Richings (*Fellow*)

GEL/1 Terminology

E. H. Jones, B.Sc.(Eng.) (*Fellow*)

GEL/1/1 Fundamental Terminology

E. H. Jones, B.Sc.(Eng.) (*Fellow*)

GEL/1/10 General Heavy Electrical Terminology

E. H. Jones, B.Sc.(Eng.) (*Fellow*)

GEL/1/20 Magnetism Terminology

E. H. Jones, B.Sc.(Eng.) (*Fellow*)

GEL/4 Graphical Symbols for Electrical Engineering and Telecommunication

R. A. Ganderton (*Member*)

GEL/6 Reliability and Maintainability

Brigadier R. Knowles, C.B.E. (*Fellow*)

GEL/111 Electromagnetic Interference

M. A. Burchall (*Fellow*)

MEE/10 Engineering Drawing Practice

D. J. Simmonds (*Member*)
G. Taylor (*Member*)

MEE/158 Mechanical Vibration and Shock

W. V. Richings (*Fellow*)

MEE/158/2 Vibration and Shock Measuring Instruments and Testing Equipment

W. V. Richings (*Fellow*)

MEE/158/6 Balancing, including Balancing Machines

W. V. Richings (*Fellow*)

NSS/5/6 Audio-Aids (School Music)

M. H. Evans (*Member*)

DPS/4 Magnetic Tape and Magnetic Disc Packs

A. Pitter (*Member*)

PEL/50 Static Power Converter Equipment

M. A. Burchall (*Fellow*)

QMS/3/4 Maintenance

L. A. Bonvini (*Fellow*)
Brigadier R. W. A. Lonsdale, C.B.E., B.Sc. (*Fellow*)

Appendix 8

Award of Institution Premiums for 1981

MAIN PREMIUMS

CLERK MAXWELL PREMIUM (*Value* £100)

For the outstanding paper on the science of electronics or radio

'Experiments on the incendivity of radio-frequency breakflash discharges (1·8–21 MHz c.w.)'
Dr. J. L. J. Rosenfield, Dr. D. C. Strachan, Dr. P. S. Tromans and P. A. Searson (*Shell Research*)

LORD MOUNTBATTEN PREMIUM (*Value* £100)

For the outstanding paper on the engineering aspects of electronics or radio

'Radio frequency ignition hazards'
D. J. Burstow, Dr. R. J. Loveland, R. Tomlinson and D. W. Widginton (*Health & Safety Executive*)

HEINRICH HERTZ PREMIUM (*Value* £75)

For the outstanding paper on the physical or mathematical aspects of electronics or radio

'Optical fibre transmission lines'
Professor W. A. Gambling, Dr. A. H. Hartog and Dr. C. M. Ragdale (*University of Southampton*)

MARCONI PREMIUM (*Value* £75)

For the outstanding paper on the engineering of an electronic system, circuit or device

'A manpack satellite communications earth station'
C. H. Jones (*Royal Signals & Radar Establishment*)

SPECIALIZED TECHNICAL PREMIUMS

PAUL ADORIAN PREMIUM (*Value* £50)

For the outstanding paper on communications or broadcasting engineering

'Optimum diversity separation for over-sea line-of-sight radio links'
A. J. Henk (*Brown & Root*)

LORD BRABAZON PREMIUM (*Value* £50)

For the outstanding paper on aerospace, maritime and military systems

'Results from an experimental dual-band search radar'
P. D. L. Williams (*Racal-Decca Marine*)

A. F. BULGIN PREMIUM (*Value* £50)

For the outstanding paper on the theory or practice of electronic components or circuits

'Semiconductor laser sources for optical communications'
Dr. P. A. Kirkby (*Standard Telecommunications Laboratories*)

ARTHER GAY PREMIUM (*Value* £50)

For the outstanding paper on production techniques in the electronics industry

'Signature analysis for board testing'
J. R. Humphrey and K. Firooz (*Hewlett Packard*)

J. LANGHAM THOMPSON PREMIUM (*Value* £50)

For the outstanding paper on the theory or practice of systems or control engineering

'A framework for systems engineering design'
Professor P. K. M'Pherson (*City University*)

CHARLES WHEATSTONE PREMIUM (*Value* £50)

For the outstanding paper on electronic instrumentation or measurement

'Characterization of single-mode optical fibres'
Dr. K. I. White, Dr. S. Hornung, J. V. Wright, Dr. B. P. Nelson and M. C. Brierley (*British Telecom Research Laboratories*)

GENERAL PREMIUMS

ERIC ZEPLER PREMIUM (*Value* £50)

For the outstanding paper on the education of electronic or radio engineers

'Integrated optics: a tutorial review'
Dr. P. J. R. Laybourn and Professor J. Lamb (*University of Glasgow*)

HUGH BRENNAN PREMIUM (*Value* £50)

For the outstanding paper first read before any of the Local Sections and published in the Journal

'A review of magnetic bubble memories and their applications'
K. F. Baker (*Formerly Plessey Research (Caswell)*)

ANNUAL ACCOUNTS OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH 1982

	1982 £	**1982** £	1981 £	1981 £
INCOME (Note 2)				
Subscriptions		319,982		260,435
Entrance, Transfer and Exemption Fees		8,453		5,648
Sales:				
Institution Journal	45,289		38,924	
Other Publications and Colloquia	27,685		16,813	
		72,974		55,737
Fees Received—Symposia		107,503		62,831
Dividends and Interest Received		1,556		439
Donation		1,873		—
Total Income		512,341		385,090
Deduct:				
Cost of Publishing Journals				
Printing Costs	80,905		79,575	
Less: Advertising Receipts	524		9,694	
Less: Applied in reduction of Advance	—		8,000	
	524		1,694	
	80,381		77,881	
Postage	31,627		30,679	
Envelopes and Wrappers	1,007		1,623	
	113,015		110,183	
Direct Expenses relating to Symposia				
Printing of Papers	22,977		6,932	
Accommodation and Travel	36,834		25,790	
	59,811		32,722	
		172,826		142,905
		339,515		242,185
Deduct:				
Administration Expenses				
Salaries and National Insurance	132,058		127,648	
Superannuation Scheme	9,877		7,912	
Postage and Telephone	17,167		15,847	
Printing and Stationery	8,569		8,013	
Computer Service	5,838		6,556	
Travelling and Entertaining Expenses	1,164		918	
Council and Committee Expenses	4,849		4,657	
Delegate Expenses	146		250	
Bank Charges	1,012		5,500	
Differences on Foreign Exchange	(3,400)		(727)	
Audit Fees	2,350		2,100	
Miscellaneous Expenses	307		1,685	
Carried forward	179,937	339,515	180,359	242,185

	1982 £	**1982** £	1981 £	1981 £
Brought forward	179,937	339,515	180,359	242,185
Establishment				
Rent, Rates and Insurance	45,364		40,437	
Lighting and Heating	2,769		2,026	
Office Expenses and Cleaning	13,198		5,451	
Repairs and Maintenance	2,774		3,438	
	64,105		51,352	
Divisions and Sections Operating Expenses				
Salaries, Printing, Stationery, Postage and Office Expenses	11,540		8,694	
Hire of Accommodation, Lectures and Meeting Expenses	6,842		4,019	
Travelling Expenses	677		738	
	19,059		13,451	
Subscriptions to the Council of Engineering Institutions	15,930		14,904	
Awards and Contributions to Other Institutions	2,690		1,080	
Depreciation (Note 3)				
Furniture, Fittings and Equipment	1,012		1,802	
Profit on Sale of Assets	—		(217)	
	1,012		1,585	
Total Expenditure		282,733		262,731
Surplus/(Deficit) for the year before Extraordinary item		56,782		(20,546)
Extraordinary Income — Secretary's General Appeal Fund		17,768		—
Surplus/(Deficit) after Extraordinary Item carried to General Fund		£74,550		(£20,546)

STATEMENT OF GENERAL FUND

	1982 £	1981 £
Adverse Balance brought forward	(71,608)	(51,062)
Surplus/(Deficit) for the Year	74,550	(20,546)
Balance at 31st March 1982	£2,942	£(71,608)

BALANCE SHEET AS AT 31st MARCH 1982

	1982 £	1982 £	1981 £	1981 £
Fixed Assets (Note 3)		72,729		71,695
Quoted Investment at Cost (Note 4)		4,317		2,823
(Market Value £4,634) (1981 £3,120)				
Premises Fund Investments (Note 6)		62,586		50,267
Current Assets				
Stock of Institution's Publications (Note 5)	18,632		25,878	
Income Tax recoverable	24		39	
Sundry Debtors and Prepayments	53,556		20,464	
Balances at Banks and in Hand	15,210		7,769	
	87,422		54,150	
Less:				
Current Liabilities				
Sundry Creditors and Provisions	44,182		41,718	
Net Current Assets		43,240		12,432
		£182,872		£137,217
Represented by:				
Fund Balances				
General Fund		2,942		(71,608)
Premises Fund Account (Note 6)		62,586		50,267
		65,528		(21,341)
Deferred Revenue				
Subscriptions and Receipts in advance		79,260		75,640
Short Term Borrowings				
Bank Overdrafts		38,084		82,918
		£182,872		£137,217

Signed

H. E. Drew (President)
S. R. Wilkins (*Honorary Treasurer*)
S. M. Davidson (*Secretary*)

24th June 1982

STATEMENT OF SOURCE AND APPLICATION OF FUNDS FOR THE YEAR TO 31st MARCH 1982

	1982 £	1982 £	1981 £	1981 £
Source of Funds				
Surplus/(Deficit) for the year after Extraordinary Income		74,550		(20,546)
Add:				
Items not giving rise to the movement of funds:				
Depreciation	1,012		1,802	
Profit on disposal of Investments and Fixed Assets	—		(217)	
		1,012		1,585
		75,562		(18,961)
Other Sources				
Increases in Subscriptions received in advance	3,620		26,648	
Premises Fund receipts	12,319		9,766	
		15,939		36,414
Total Source of Funds		91,501		17,453
Application of Funds				
Purchase of Fixed Assets and Investment (Net)	3,540		4,791	
Amount set aside for Premises Fund Investment	12,319		9,766	
		15,859		14,557
		£75,642		£2,896
Represented by:				
Movement in Working Capital:				
(Increase)/Decrease in Stocks	7,246		5,909	
(Increase)/Decrease in Tax Recoverable	15		(7)	
(Increase)/Decrease in Debtors	(33,092)		8,690	
Increase/(Decrease) in Current Liabilities	2,464		(7,402)	
		(23,367)		7,190
Movement in Net Liquid Funds:				
Decrease in Bank Overdraft	(44,834)		(7,866)	
Increase in Bank and Cash Balances	(7,441)		(2,220)	
		(52,275)		(10,086)
		£(75,642)		£(2,896)

NOTES FORMING PART OF THE ACCOUNTS FOR THE YEAR ENDED 31st MARCH 1982

1. The accounting policies adopted by the Institution are disclosed, where appropriate, in the notes below.

2. **Income**
The accounting policies adopted by the Institution for treatment of income are summarized as follows:

(i) *Subscriptions:* This represents amounts received by the Institution in respect of the subscription year to 31st March 1982, together with any arrears of subscriptions collected in the period. Subscriptions received in advance are carried forward as Deferred Revenue to future years.

(ii) *Journal and Publication Sales: Symposia Fees:* These represent amounts receivable in respect of Symposia programmed for the year, and for publications supplied during the year. Journal subscriptions received in advance are carried forward as Deferred Revenue to future years.

(iii) *Dividends and Interest received: Entrance, transfer and exemption fees:* These represent amounts actually received in the year.

3. Fixed Assets

The United Kingdom fixed assets of the Institution were revalued by the Secretary, acting on specialist advice, on the basis of market value at 31st December 1977. The surplus so arising was dealt with in the accounts for 1977/78.

It is the policy of the Institution to maintain its Library and Furniture in such a manner that their value is not affected by the effluxion of time. Such expenditure is charged against revenue when incurred. Consequently, the Institution does not consider it necessary to provide depreciation on fixed assets other than those located overseas together with UK equipment.

Depreciation of UK equipment and overseas furniture and equipment is based on net book value at rates between 10% to 25% per annum.

	Furniture and Equipment £	*Library* £	*Total* £
Cost or Valuation			
As at 1st April 1981:			
at Cost	9,921	7,222	17,143
at Valuation	22,000	36,000	58,000
	31,921	43,222	75,143
Additions during the year at Cost	12	2,034	2,046
As at 31st March 1982	£31,933	£45,256	£77,189
at Cost	9,933	9,256	19,189
at Valuation	22,000	36,000	58,000
Depreciation			
As at 1st April 1981	3,448	—	3,448
Provision for the Year	1,012	—	1,012
As at 31st March 1982	£4,460		£4,460
Net Book Values			
As at 31st March 1982	£27,473	£45,256	£72,729
As at 31st March 1981	£28,473	£43,222	£71,695

4. Quoted Investments

Nominal		*Cost* £
£1,000	$7\frac{3}{4}\%$ Barnet Corporation Loan 1982/84	982
£270	Inchcape & Co. Ltd.—$12\frac{1}{2}\%$ Unsecured Loan Stock 1993/98	99
£1,000	Islington Corporation—10% Redeemable Stock 1982/83	995
166	Muirhead Limited—25p Ordinary Shares	262
£500	Stock Exchange—$7\frac{1}{4}\%$ Mortgage Debenture Stock 1990/95	485
390	Racal Electronics Ltd—25p Ordinary Shares	1,494
£1,220	$5\frac{1}{2}\%$ Treasury Stock 2008/12 (donated)	—
		£4,317

The Institution also has a residuary interest in a settlement consisting of freehold property which will be vested in the Institution at some future date. The Secretary estimates the value of this interest to be approximately £11,000 at 31st March 1982.

5. Stock of Institution's Publications

Stock of the Institution's publications is stated at the lower of cost, including appropriate overheads, and net realizable value.

6. Premises Fund

	1982 £	1981 £
Investments:		
London Borough of Hillingdon—12% Bonds	53,000	—
Inverclyde City Council—Term Loan	—	43,000
Balance at Bank	9,586	7,267
	£62,586	£50,267
Movement on Fund during year:		
Balance 1st April 1981	50,267	40,501
Add:		
Receipts during year:		
Donations	1,329	1,381
Covenanted Subscriptions	3,723	3,866
Interest received on Investment	7,267	4,519
Balances 31st March 1982	£62,586	£50,267

7. Foreign Exchange

Fixed Assets located overseas have been converted to Sterling at the rate of exchange ruling when the asset was purchased.

Overseas remittances and receipts during the year have been converted into Sterling at the current rates then ruling and the bank and cash balances held overseas at 31st March 1982 at the rate of exchange ruling at that date.

AUDITORS' REPORT TO THE MEMBERS OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

We have audited the accounts set out on pages 462 to 464 in accordance with approved Auditing Standards.

In our opinion the accounts, which have been prepared under the historical cost convention as amended by the revaluation of certain assets by the Secretary of the Institution as described in Note 3, give a true and fair view of the Institution's affairs at 31st March 1982 and of the surplus and source and application of funds for the year ended on that date, and comply with the Royal Charter and Bye-Laws of the Institution.

50 Bloomsbury Street, London WC1B 3QY
24th June 1982

GLADSTONE, JENKINS & CO.
Chartered Accountants

Obituary

The Institution has learned with regret of the deaths of the following members.

Ronald Bolton (Fellow 1962, Member 1952, Associate 1948) of Wexham, Slough, died early this year aged 65. Ronald Bolton was for some years before the war with the Instruments Section of Blackpool Electricity Department and after service in the Royal Signals was for some years with the Post Office Engineering Department. In 1949 he transferred to the East African Posts and Telecommunications Administration as an Assistant Engineer and remained with this organization until 1964, eventually becoming Director of Posts and Telecommunications for Tanganyika. In 1966 he retired and joined London Transport as a Senior Executive responsible for communications equipment installation and maintenance. In 1974 he was promoted to be Principal Communications Assistant (Design) in the Department of the Chief Signal Engineer. He retired from the position in 1979.

Lieutenant Commander Dennis Burford, RN (Member 1969, Graduate 1964) of Helston died early in 1982, aged 49 years. A graduate of Trinity College Dublin in engineering, Commander Burford was a specialist in airborne electronic equipment.

Ernest Cooper (Member 1957, Graduate 1954, Student 1947) of Llandaff, died early in 1982, aged 81 years. A graduate of the University of Wales, Mr Cooper was, prior to his retirement in 1966, lecturer in physics at Cambridgeshire Technical College.

Roy Joseph Crumpen (Graduate 1966) of Longfield, Kent, died recently, aged 62. His last notified appointment was as a Technical Author in the Guided Weapons Branch of HQ Technical Group REME, Woolwich.

Sydney Charles Dudman (Member 1968) of Walderslade, Kent, died on 21st March 1982, aged 62 years. Following eight years service in the Merchant Navy as a Radio Officer, Mr Dudman studied for a degree of London University in electrical engineering at Queen Mary College which he received in 1950. From 1950 to 1957 he was an electronics engineer with EMI in Hayes and Feltham and in 1957 he moved into technical education, his first post being at Norwood Technical College. Three years later he was appointed a Lecturer at Medway College of Technology and was then promoted to Senior Lecturer in 1965.

Douglas Ronald Earl (Associate Member 1973, Associate 1971) of Highcliffe-on-Sea died on 1st June 1982, aged 54 years. Mr Earl was a Technical Officer attached to the Headquarters of Technical Group Royal Electrical and Mechanical Engineers.

Squadron Leader Frederick Henessy Harper, RNZAF (Retd) (Member 1961) of Wellington, New Zealand, died early in 1982, aged 68. His staff appointments included those of Deputy Director, Communications (1950–52) and Officer-in-Charge of RNZAF Radio Servicing (1958–61).

Group Captain Kenneth William Haynes, RAF (Retd) (Member 1951) of Brackley, Northants, died on 30th April 1982, aged 64 years. Kenneth Haynes served during the war as a Station Signals Officer in No. 100 Group, and subsequently held appointments in Singapore, at the Central Servicing Development Establishment and at the RAF Technical College. Following a period at the RAF Staff College he was attached to HQ Allied Air Forces Northern Europe; he was for two years at RAF Bentley Priory and later at the Ministry of Defence as Deputy Director of Weapons Engineering. His final service post was Command Communications and Electronics Officer of the Far East Air Force in Singapore. In 1970 he retired from the RAF and was appointed Manager for British Aircraft Corporation, Guided Weapons Division in Singapore and he held a similar post in Tehran from 1972 to 1974 when he returned to the Company's headquarters in England.

William Boyd McFee (Associate 1950) of Helensburgh died on 6th September 1981, aged 67 years.

Alan David Pitt (Member 1973, Graduate 1974) of Bristol, died in January 1982, aged 52 years. He was from 1969 with British Aerospace, Filton and his posts included that of Cleanliness Assurance Manager for a number of Earth Satellite projects.

Major-General Henry Ernest Roper, C.B. (Fellow 1978, Member 1953) of Christchurch, Dorset, died on 13th July 1982, aged 59 years.

Commissioned in the Royal Signals in 1942, Harry Roper served in North West Europe and South East Asia. After the war he obtained a B.Sc.(Eng.) external degree of London University following study at the Royal Military College of Science. He spent a period as an Instructor at the School of Signals, and was subsequently Officer Commanding Independent Signals Squadrons in BAOR and in Cyprus with the rank of Major. From 1961–62 he was on the Directing Staff at the Royal Military College of Science and from 1968–70, with the rank of Brigadier, was United Kingdom Director of Project Mallard. After three years as Chief Signals Officer at the Headquarters of BAOR, he returned to the Ministry of Defence as Assistant Chief of General Staff (Operational Requirements). From 1976–80 he was Colonel Commandant of the Royal Signals and was appointed a C.B. in 1976. General Roper retired from the Army in 1978 and after a period with Standard Telephones and Cables as Manager, Military and Public Sector Marketing, he joined Plessey Defence Systems as Director and General Manager of Project Ptarmigan.

General Roper served on the Membership Committee from 1960–61 and from 1978–81 served as a member of the Council of the Institution. He was elected a Vice-President in 1981 and had been nominated to serve for the coming year.

Robert Thirkell (Graduate 1967) of Houghton-le-Spring, died on 22nd February 1982, aged 48. After working for some 14 years with the Post Office, he had since 1963 been an Assistant Engineer (Telecommunications) with the Central Electricity Generating Board.

Professor Harry Frederick Trewman (Fellow) of Chislehurst died on 4th November 1981 aged 89 years.

A graduate of Cambridge University where he read Mathematics and Engineering at Emmanuel College obtaining first class honours in both Tripos, Harry Trewman served in the infantry in World War I. He entered technical education in 1920 as a Senior Lecturer in electrical engineering at the Military College of Science and from 1926 to 1939 was Professor of Electrical and Mechanical Engineering at the College. During World War II he was for four years attached as Technical Adviser to the Inspection Department concerned with electronic instruments and from 1943 to 1945 he was Assistant Director of Instrument Production.

After the war, Professor Trewman was appointed Managing Director and Principal of E.M.I. Institute, which had been set up by the well known electronics company, and subsequently became the EMI College of Electronics. This venture expanded also into what is now termed 'distance learning', and on his retirement Professor Trewman became associated with the Cleaver-Hume Group, subsequently Crowell Collier and Macmillan Schools, as Advisory Principal. In 1963 he was concerned with the setting-up of the Correspondence College Standards Association and was its Honorary Secretary for several years.

An interesting tribute to Harry Trewman's war-time contributions to radar and other electronic developments was paid in 1972, on the initiative of Dr H. R. Wilkins, Director of Lunar Research of the British Astronomical Association, who had worked on these projects with Professor Trewman. An area of the Moon, surveyed by Dr Wilkins has been identified on his 300 inch diameter lunar map as 'Trewman'. This area is situated near the periphery of the Moon, at almost '7 o'clock' on its face and is included in the international nomenclature approved by the International Astronomical Union.

Professor Trewman was, during his long professional career, associated with many organizations and activities. One which brought him into closest contact with this Institution was as the representative of the Radio Industry Council on the Radio Trades Examination Board, constituted by the three main trade associations and the Institution.

Wang Shaw-Thang (Associate Member 1976) of Singapore, died earlier this year aged 49 years. A graduate in physics of Nanyang University, Singapore, he was a senior science and technical teacher at the Chung Hwa Girls' High School.

IERE BENEVOLENT FUND

Annual Report of the Trustees for the period 1st April 1981 to 31st March 1982

The IERE Benevolent Fund had its beginnings in 1932 when donations from a few founder members were credited to a special account for the relief of colleagues and their dependants in time of need. Since then the arrangements for the holding and administration of the Institution's benevolent resources have been formalized progressively—a process which culminated in the registration of the definitive Trust Deed in 1980. The Trustees are accordingly pleased to report that the revised legal and financial arrangements for the management of the IERE Benevolent Fund's affairs, which were completed in 1980/81, settled down quickly and are now working well. Opportunity was therefore taken during the year under report to review the Fund's investments and to ensure that the flexibility offered by the terms of the Fund's Trust Deed was used to best advantage. As a result, as will be readily apparent from the schedule of investments attached to the Annual Accounts, the Fund's portfolio has been drastically revised—the 1980/81 holding of 43 different stocks and shares giving a gross income of £5,537 per annum has been restructured into only 19 holdings promising a gross income of £9,813 per annum. Donations and legacies at a very much more encouraging level during the year were taken into account when making these reinvestment decisions.

There has been no material increase in the rate of calls on the Fund's resources during the year. All deserving cases covered by the terms of the Fund's Trust Deed have been accommodated sympathetically and constructively. Other deserving cases, but outside the Trust Deed's remit, have been referred, wherever possible, to other more likely sources of help. The Trustees feel, nevertheless, that there is probably more the Fund could do if only its availability was more widely publicized by members who find themselves in contact with colleagues or dependants who are in need but reluctant to accept charitable aid. All such cases should be encouraged to contact the Trustees of this their own Benevolent Fund to ensure that, wherever possible, the intentions and wishes of the founding fathers of the Fund can be implemented and honoured.

ANNUAL ACCOUNTS OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS BENEVOLENT FUND

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH 1982

	1982 £	1982 £	1981 £	1981 £
INCOME				
Donations		9,695		830
Dividends and Interest Receivable		8,249		8,230
		17,944		9,060
EXPENDITURE				
Legal and Professional Charges	516		210	
Grants and Donations	2,013		2,005	
Administrative Costs, Postage, Telephone and Stationery	454		302	
		2,983		2,517
		14,961		6,543
Add:				
Surplus on redemption and disposal of investments		6,622		385
Surplus for the year carried to Reserve Account		£21,583		£6,928

BALANCE SHEET AS AT 31st MARCH 1982

	1982 £	1982 £	1981 £	1981 £
ASSETS				
Investments at Cost Market Value at 31/3/82: £125,162 (1981 £85,709)		87,848		50,319
Short Term Deposits and Loans		21,491		27,279
Current Assets				
Bank Balances on Current Account	248		—	
Income Tax Repayment Claim	171		495	
Sundry Debtors	332		600	
Amount due from IERE	—		25	
		751		1,120
		110,090		78,718
Less:				
Current Liabilities				
Legal and Professional Charges Payable	516		161	
Amount due to IERE	326		—	
Amounts due on purchase of Investments	9,108		—	
		9,950		161
		£100,140		£78,557
Represented by:				
Reserve Account—Balance 1st April 1981		78,557		71,629
Add:				
Surplus for the year		21,583		6,928
Balance at 31st March 1982		£100,140		£78,557

Trustees:
Signed
Harry E. Drew
S. R. Wilkins
S. M. Davidson

20th August 1982

SCHEDULE OF INVESTMENTS AS AT 31st MARCH 1982

Nominal		*Cost* £
1,000	The Bowater Corp. Ordinary £1 Shares	2,515
1,500	B.T.R. Ordinary 25p Shares	5,281
£2,206.59	Corporation of London $6\frac{1}{2}$% Loan 1980/82	1,800
2,249	G.E.C. 25p Ordinary Shares	885
600	G.E.C. Unsecured Capital Notes 1986	—
£2,188.43	Greater London Corporation $9\frac{1}{2}$% Loan 1980/82	2,000
1,124	I.C.I. Ordinary £1 Shares	3,334
8,822	Marks & Spencer 25p Ordinary Shares	5,470
2,500	Percy Bilton 25p Ordinary Shares	5,036
2,000	Plessey Co. 25p Ordinary Shares	4,341
2,000	Racal Electronics 25p Ordinary Shares	7,625
2,000	Shell Transport & Trading 25p Ordinary Shares	3,140
1,330	Transport Development Group 25p Ordinary Shares	743
£3,235.80	12% Treasury Stock 1986	2,890
£1,500	12% Treasury Loan 1983	1,432
£5,000	13% Treasury Stock 1990	4,934
£17,500	13% Treasury Stock 2000	16,810
£17,500	$13\frac{3}{4}$% Treasury Stock 2000/03	17,314
2,000	Watts, Blake, Bearne & Co. 25p Ordinary Shares	2,298
		£87,848

AUDITORS' REPORT TO THE TRUSTEES OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS BENEVOLENT FUND

We have audited the accounts set out on pages 466 to 467 in accordance with approved auditing standards. In our opinion the annexed accounts show a true and fair view of the Benevolent Fund's affairs at 31st March 1982 and of the surplus for the year ended on that date, and comply with the Trust Deed dated 22nd May 1980.

50 Bloomsbury Street, London, WC1B 3QY
20th August 1982

GLADSTONE, JENKINS & CO.
Chartered Accountants

The D. R. Chick Laboratory

The Ion Implantation Laboratory of the University of Surrey's Department of Electronic and Electrical Engineering has been formally dedicated to the Department's former Head, Professor Douglas Chick (Fellow) who died on 11th June 1978.*

At a ceremony held on 14th July, Mrs M. E. Chick unveiled a plaque in the Laboratory commemorating the achievements of her late husband as a member of the famous Watson-Watt radar team during World War II, as Leader of the Nuclear Sciences Group of AEI's research laboratory at Aldermaston Court and, from 1965, as Head of what is now the Department of Electronic and Electrical Engineering at the University of Surrey.

Among his many achievements at Surrey was his appreciation in 1966 of the need for research work on ion implantation, long before industry realized its potential in microelectronics. The Department's Ion Implantation Group is internationally recognized for its research and its laboratory receives special support from the Science & Engineering Research Council as a centre of excellence. The facilities in the laboratory are also made available to external users in universities and industry.

At the unveiling ceremony Professor Stanley Hunt of Aston University, a former colleague of Professor Chick at Aldermaston, said of him, 'My very first impression of him as a person of tremendous imagination and foresight, coupled with boundless energy, remained valid throughout our long and happy association. He had a fine inventive mind and an urge to put theory into practice at the first possible opportunity. He was a sincere and loyal friend.'

Professor Chick served on Institution Committees in the fifties and sixties and on the Council from 1954 to 1957. The President of the Institution, Mr Harry Drew, one of his wartime associates, was present at the dedication ceremony.

The Radio and Electronic Engineer*, **48, no. 10, p. 532, October 1978.

Standard Frequency and Time Service

(Communication from the National Physical Laboratory)

Relative Phase Readings in microseconds
NPL—Station
(Readings at 1500 UT)

JULY 1982	MSF 60 kHz	GBR 16 kHz	Droitwich 200 kHz
1	−12·1	33·5	33·8
2	−12·2	33·3	33·6
3	−12·2	33·5	33·4
4	−12·1	33·4	33·3
5	−12·3	33·5	33·1
6	−12·4	33·3	33·0
7	−12·5	33·4	32·8
8	−12·8	33·7	32·6
9	−12·8	33·3	32·3
10	−12·8	33·2	32·0
11	−12·9	33·3	31·7
12	−12·7	34·3	31·5
13	−12·8	33·6	31·0
14	−12·9	34·5	30·5
15	−12·9	33·0	30·3
16	−12·8	33·5	30·1
17	−12·9	33·7	29·9
18	—	—	29·7
19	—	—	29·5
20	—	—	29·3
21	—	—	29·1
22	—	—	28·9
23	—	—	28·7
24	—	—	28·4
25	—	—	28·2
26	—	—	27·8
27	—	—	27·0
28	−12·8	—	26·2
29	−13·0	33·0	25·8
30	−13·1	32·6	25·4
31	−13·0	—	25·1

Notes: (a) Relative to UTC scale (UTC_{NPL}–Station = +10 at 1500 UT, 1st January 1977.
(b) The convention followed is that a decrease in phase reading represents an increase in frequency.
(c) 1 μs represents a frequency change of 1 part in 10^{11} per day.
(d) It may be assumed that the related stations on 200 kHz at Westerglen and Burghead will follow the day to day changes in these phase values.

UDC 621.317.32:621.375:621.391.822:681.32

Indexing Terms: Automatic testing equipment, Amplifier noise figure measurement, Computer controlled measurement

Automatic noise figure measurements with computer control and correction

D. A. ABBOTT, B.Sc.†

and

H. V. SHURMER, Ph.D., D.Sc.(Eng.), C.Eng., FIEE*

SUMMARY

By using computer control and correction, the noise parameters of an amplifying device can be obtained as an immediate display from system noise measurements without the need of having subsequently to make tedious calculations. The means of achieving this are described in the paper, together with results obtained by applying the facility to microwave amplifiers incorporating GaAs f.e.t. devices mounted in microstrip.

* *Department of Engineering, University of Warwick, Coventry CV4 7AL.*

† *Formerly at the University of Warwick; now with Computer Measurement Service, MEL, Manor Royal, Crawley, West Sussex RH10 2PZ.*

1 Introduction

This development has centred upon the noise characterization of GaAs f.e.t. devices as microwave amplifiers, but the attainments are not limited to the assessment of a particular type of device. In a conventional equipment for the automatic display of overall noise figure, although the indicated value may be tuned to a minimum, this will not in general correspond to the minimum device noise figure. Problems arise in extracting the true device noise figure by calculation, owing to tuning effects. Furthermore, full characterization requires a knowledge of the optimum source impedance and noise resistance, which involve separate measurement procedures.

An initial system was based on the use of a Precision Automatic Noise Figure Indicator (Ailtech Type 75), but this was subsequently replaced by a System Noise Monitor (Ailtech Type 7380). Another important component, developed for the project, was a calibrated slotted-line tuner, controlled via stepping motors by the computer, a Rank Xerox Sigma 5 with remote graphics terminal. The computer is used to control the measurements, collate results and perform mathematical manipulations.

Software development was a major task and had to keep step with a succession of changes in hardware and techniques, resulting eventually in an interactive program with an overlay structure, to make efficient use of limited core storage. In addition to the overall control function, the computer is used for the automatic plotting of circles of constant noise figure on a Smith chart display, comparison of curve-fitting routines and the computation of various 'figures of merit' to evaluate the effects of software changes.

2 Noise Representation

In general, we are concerned with the properties of noisy two-port networks, of which an amplifier is a special case.[1] If we initially consider the elementary $(ABCD)$ matrix representation of a noiseless network, then the input voltage and current, V_i and I_i, are related to the output voltage and current, V_0 and I_0 by equation (1):

$$\begin{aligned} V_i &= AV_0 + BI_0, \\ I_i &= CV_0 + DI_0. \end{aligned} \quad (1)$$

If there are noise sources present inside the two-port network, the equation must be modified accordingly.

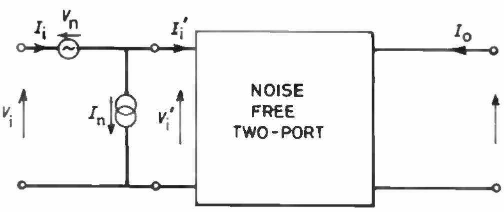


Fig. 1. Elementary representation of noisy 2-port network.

The most convenient representation uses only noise sources that precede the noise-free two-port. This situation is shown in Fig. 1, where noise sources V_n and I_n are shown preceding the noise-free two-port and is

0033–7722/82/100468+07 $1.50/0

described by equation (2):

$$V_i = AV_0 + BI_0 + V_n,$$
$$I_i = CV_0 + DI_0 + I_n. \tag{2}$$

If the noise sources V_n and I_n are partially correlated then each may be expressed as the sum of its correlated and uncorrelated parts. Therefore, for the current source,

$$I_n = I_c + I_u,$$

where I_c is the current that is totally correlated with the noise source V_n, and I_u is the current which is totally uncorrelated.

The correlated noise current, I_c, may be expressed as $Y_{cor} V_n$, where Y_{cor} is the complex correlation admittance. Therefore, referring to Fig. 1, the input current is

$$I_i = I_n + I_i'$$
$$= I_u + Y_{cor} V_n + I_i'$$

and the input voltage is

$$V_i = V_n + V_i',$$

i.e.

$$V_n = V_i - V_i'.$$

Combining these relationships gives

$$I_i = I_i' + I_u + Y_{cor}(V_i - V_i'). \tag{3}$$

The circuit described by this equation is shown in Fig. 2.

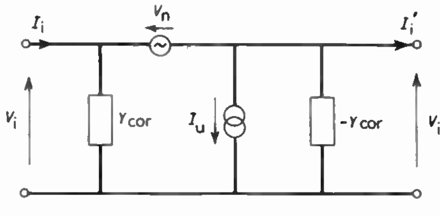


Fig. 2. Equivalent circuit of 2-port network with partial correlation of noise sources.

When a current source I_s is added across the input terminals, with internal admittance Y_s, then the total short-circuit current at the output of the noise-source network, I_{tot}, is given by:

$$I_{tot} = I_s + I_u + V_n(Y_s + Y_{cor}).$$

Since these component currents are uncorrelated with each other, we have

$$\overline{|I_{tot}|^2} = \overline{|I_s|^2} + \overline{|I_u|^2} + \overline{|V_n|^2}\, |Y_s + Y_{cor}|^2. \tag{4}$$

One definition of noise figure F is the ratio of the total output noise power per unit bandwidth available at the output port to that portion of it due to the source. Hence

$$F = \overline{|I_{tot}|^2} / \overline{|I_s|^2}$$
$$= 1 + \frac{\overline{|I_u|^2} + \overline{|V_n|^2}\, |Y_s + Y_{cor}|^2}{\overline{|I_s|^2}}. \tag{5}$$

Using the Nyquist relationships:

$$\overline{|I_u|^2} = 4kT_0 G_u \Delta f$$
$$\overline{|I_s|^2} = 4kT_0 G_s \Delta f \tag{6}$$
$$\overline{|V_n|^2} = 4kT_0 R_n \Delta f$$

where k = Boltzmann's constant, $T_0 = 290$ K, Δf = incremental frequency band, and G_u, G_s and R_n are the noise conductance, source conductance and noise resistance respectively.

Substituting into equation (5) leads to

$$F = 1 + \frac{G_u + R_n |Y_s + Y_{cor}|^2}{G_s}. \tag{7}$$

Minimizing F with respect to Y_s leads to an optimum value of source admittance $Y_0 = G_0 + jB_0$, where

$$G_0 = \left| \frac{G_u + R_n G_{cor}^2}{R_n} \right|^{\frac{1}{2}}$$

and

$$B_0 = -B_{cor}. \tag{8}$$

Substitution into equation (7) gives an expression for the minimum noise figure, F_0:

$$F_0 = 1 + 2R_n(G_{cor} + G_0). \tag{9}$$

In terms of F_0, the noise figure F for any source admittance, is given by

$$F = F_0 + \frac{R_n}{G_s} |Y_s - Y_0|^2. \tag{10}$$

Thus, without any assumptions about the noise mechanisms within a noisy two-port network, the noise figure may be expressed as an explicit function of the minimum noise figure and of the source admittance.

3 Measurement of Noise Figure in Linear Two-ports

The measurement technique employed was essentially that of Y-factor measurement,[2] illustrated in Fig. 3.

The device under test (d.u.t.) is connected in turn to two terminations at temperatures T_1 and T_2, respectively, the output being detected by a receiver, following down-conversion and i.f. attenuation stages.

Denoting the corresponding output powers by P_1 and P_2, we have

$$P_1 = (T_1 + T_e)kBG$$

and

$$P_2 = (T_2 + T_e)kBG \tag{11}$$

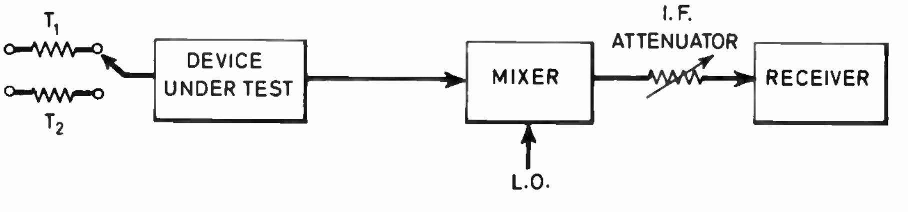


Fig. 3. Basic Y-factor measurement.

where T_e is the equivalent input noise temperature, B the signal bandwidth and G the power gain of the d.u.t.

If Y represents the attenuation required for equality of P_1 and P_2, it is clear that

$$Y = \frac{T_2 + T_e}{T_1 + T_e}.$$

Hence

$$T_e = \frac{T_2 - YT_1}{Y - 1}. \quad (12)$$

The noise figure F is expressed in terms of T_e by

$$F = \frac{T_e}{290} + 1. \quad (13)$$

The above expression for F includes noise contributed by both the mixer and receiver, but these contributions may be eliminated mathematically.[3] If the mixer and receiver are lumped together as the 'measurement system', characterized by a gain G_M and a noise temperature T_M, the d.u.t. being characterized by corresponding quantities G_D, T_D, we may write for the output noise powers, with T_1 and T_2 connected, respectively:

$$P_1 = |(T_1 + T_D)G_D + T_M|G_M,$$
$$P_2 = |(T_2 + T_D)G_D + T_M|G_M. \quad (14)$$

Using these equations, together with equation (13), leads to an expression for device noise figure F_D in terms of overall system noise figure and measurement system noise figure F_S, F_M, respectively:

$$F_D = F_S - \frac{F_M - 1}{G_D}. \quad (15)$$

The device noise figure is thus less than the measured system noise figure by a correction factor which is dependent on both the device gain and the noise figure of the measurement system. Whilst the technique is satisfactory for measuring the noise figure of fixed units, the requirements for switching, gain measurement and noise figure calculation render the system impractical for the purpose of tuning or aligning amplifiers. The alternative tuning for a minimum indicated noise figure can give a result significantly different from minimum device noise figure, depending on the amplifier gain and mixer noise figure.

The Y-factor method provides the basic principle of the Precision Automatic Noise Figure Indicator (PANFI) illustrated schematically in Fig. 4. The noise source is used to give a square-wave modulated input signal source to the d.u.t., which feeds a broad-band double-balanced image rejection mixer, whose output at i.f. comprises amplified modulated noise. The following stage, a square-law detector, gives a similarly modulated output signal whose two levels of voltage are proportional to the levels of noise power in the i.f. signal. A sample of the detected signal is supplied to an a.g.c. loop, in which the amplifier is gated to be operative only during the 'off' period of the noise generator, thereby keeping at a constant level the output during this interval. The higher level of output voltage, inversely proportional to the d.u.t. noise figure, is used to drive a meter via an integrator gated at about 400 Hz. The meter thus gives an immediate indication of noise figure, enabling tuning for a minimum value to be effected.

The Ailtech System Noise Monitor (SNM) operates along similar lines but is refined so as to give digital indications of both system gain and noise figure, with the additional facility of BCD-coded outputs, thereby facilitating automatic data collection and processing, including the calculation of d.u.t. noise figure. With neither of these instruments, however, does tuning for minimum indicated noise figure yield a true minimum noise figure for the device, for reasons previously indicated.

Standard practice has been to measure system noise figure and d.u.t. gain at each tuned frequency, applying equation (15) until a minimum is found for F_D. However, equation (10) indicates that for full device characterization three individual parameters must be determined, one of which is a complex quantity. Conventionally, this requires the use of a separate admittance measuring instrument in conjunction with a measurement of device noise figure under some different source loading condition, which involves a sequence of connections and disconnections. Not only is this procedure tiresome, it is also very susceptible to error, particularly if characterization over a wide operating range is required.

The key to a simpler and more satisfactory solution is given by equation (10), which describes noise figure as a function of Y_s, assuming the remaining parameters are fixed. Bearing in mind that Y_0 in that equation is

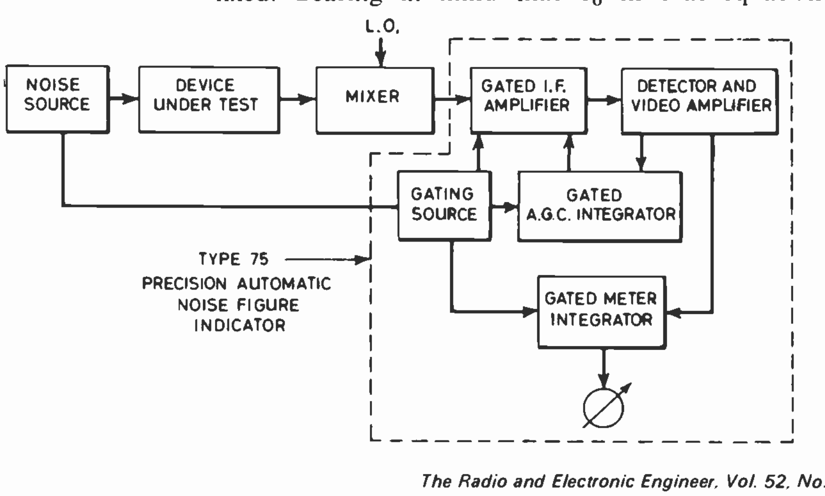


Fig. 4. Automated Y-factor measurement.

complex, a measurement of noise figure at four independent values of Y_s is sufficient to enable the four noise parameters to be determined. In practice, following Lane,[4] the number of values we have employed for Y_s has varied between 8 and 40, in conjunction with a curve-fitting procedure, thereby greatly enhancing the accuracy of determining the noise parameters.

4 System Development

The development of a fully automated system based on the techniques described in the last Section involved three distinct and progressive phases, each one introducing significant changes of both hardware and software.

4.1 Manual System

In order to check the performance of newly-purchased equipment and to examine the applicability of the theory, a manual system was initially arranged, of the form illustrated in Fig. 5.

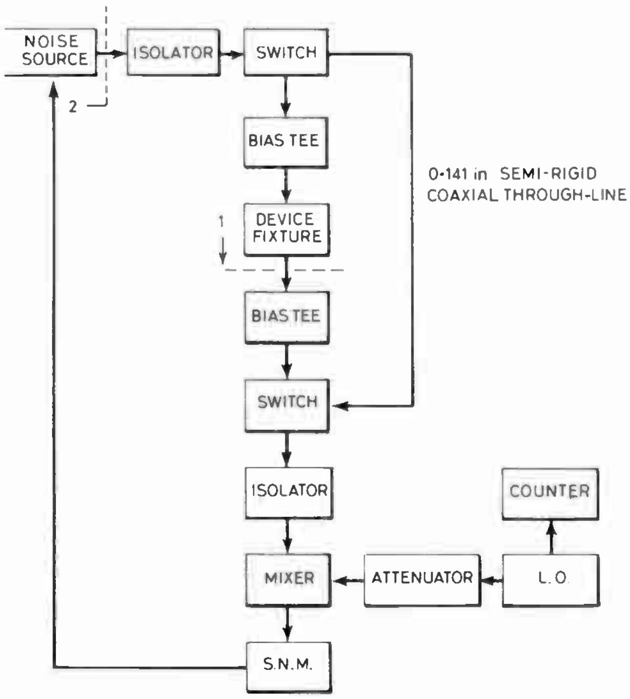


Fig. 5. Manual system arrangement.

This shows a fairly conventional noise figure measurement system with a switchable 'through-line' for gain setting. The device fixture, in addition to securing the device, served to permit the presentation of a variable source admittance through the connection of different microstrip circuits, previously characterized using an automatic network analyser (ANA).[5] Two sets of substrates were used for these circuits, polyguide for 3 GHz and alumina for 10 GHz.

Three calibration measurements were involved in this system, the first being a determination of noise figure, referring to plane 1, from which the second stage noise contribution could be evaluated. The second of the measurements related to plane 2 and gave the input loss, the device fixture being short-circuited for this purpose. Thirdly, the gain correction was determined via a further measurement at plane 2, this time with the 'through-line' switched into circuit. The calibration results were found to be very stable with time and could be re-employed over several measurement sessions.

In the manual system, the values of gain and noise figure indicated by the SNM were recorded for each operating condition and for each value of source admittance. When all source admittance values had been presented to the d.u.t., the recorded data were corrected manually for system losses and second-stage noise contribution. The results were presented as data to the computer in the form of a card deck, a curve-fitting routine then being operated in conjunction with equation (10) and minimizing the function

$$\sum_{i=1}^{n} \left| F_i - \left(F_{\min} + \frac{R_n}{G_s} |Y_i - Y_{\mathrm{opt}}|^2 \right) \right|^2,$$

F_i being the noise figure as measured for each source admittance Y_i, the parameters $F_{\min}$, R_n and Y_{opt} being adjustable. Hence the four required noise parameters were obtained and, in addition, the program also derived the noise figure and its deviation from the measured value, for each admittance setting. On a typical run involving eight such settings this deviation would not exceed 0·1 dB. Centres and radii for circles of constant noise figure, referred to the source plane, were also evaluated by the program for plotting on a Smith chart.

The main disadvantages of the manual system related to the considerable labour involved and to the delay between measurement and analysis. Nevertheless, this stage proved invaluable in confirming the correctness of the overall approach and the details of the computational techniques for characterizing microwave devices.

4.2 Semi-automatic System

The major improvement in hardware at this stage was the introduction of a trough-line tuner, which could be quickly and accurately set to any predetermined admittance value, following calibration via the ANA. This eliminated the need for a set of microstrip components each giving a fixed source admittance. An upper frequency limit of 8 GHz was set by the physical dimensions of the anodized slug within the tuning cavity but measurements aimed at developing the system were confined to the range 2–4 GHz.

Complementary to the hardware change, an interactive on-line analysis program was developed and introduced in successive stages. The first step involved use of magnetic tape and a rapid-access disk instead of a card deck, with processing immediately following a measurement sequence. The next modification involved automatic rather than manual correction of data, followed by the introduction of a procedure, involving a v.d.u., whereby the operator was conducted through the various action stages required over a full sequence of measurements.

As the program outgrew the allocated foreground storage available, use was made simultaneously of both foreground and background memory locations, leading

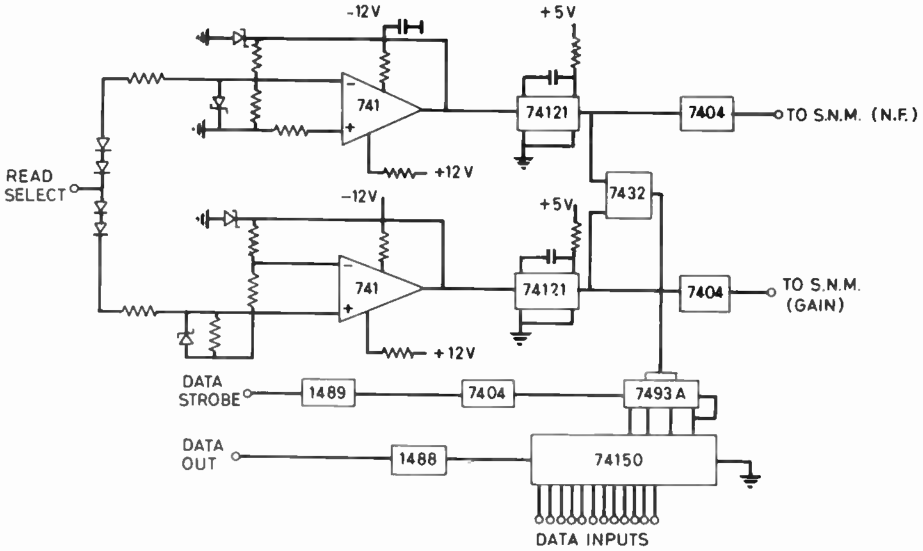


Fig. 6. Interface circuitry.

eventually to an overlaid system in which segments of the program were taken in sequence from disk and held in memory for a limited period only. This enabled the most efficient use to be made of the available memory and permitted a sophisticated program to be run in a multiplexed mode simultaneously with other users.

4.3 Fully Automatic System

In this phase full automation of the tuning procedures, data collection and processing were accomplished, starting with the replacement of a routine for manual data entry by a procedure for automatic reading of the SNM.

For this purpose, use was made of a facility providing both noise figure and gain in digital form as outputs from the SNM. These parameters are presented as three decimal digits, each requiring four binary bits. This led to the need for multiplexing, since only ten data lines connected the Measurements Laboratory to the computer and various other signals had also to be transmitted, such as a command to read data or select a particular parameter. Multiplexing was effected by means of the interface network illustrated in Fig. 6.

An input reading is initialized by a pulse into the READ SELECT terminal. Depending on polarity, this activates one of two parallel paths, each incorporating an operational amplifier (741) and a monostable multivibrator (74121). In this way, it is ensured that a pulse having the correct polarity, voltage and duration is applied to the SNM for the purpose of reading either gain or noise figure. Some 25 ms later, data from the SNM becomes 'valid' for transmission to the computer. The data inputs are connected to a multiplexer (74150) and are read by the computer, one bit at a time, by cycling a counter (7493A). Initialization of the counter is effected when a READ DATA pulse occurs on either of the gain or noise figure lines from the SNM. Two interface devices (1488, 1489) enable 10 V pulses to be carried between the computer and interface, thus providing high noise immunity.

By the above means, some 15 input/output lines were accommodated within 3 actual links between the computer and the laboratory. The method of controlling pulse polarity, duration and delay was by means of machine code sub-routines introduced within the main *Fortran* program. The auto-read facility was developed in conjunction with the manually-controlled tuner, but the introduction of a computer-controlled tuner necessitated a major expansion of the software.

There were two main requirements for the tuner, the first being the need for easy interfacing and the second flexibility in setting admittance values, so as to cater for various types of device over a broad frequency range. The combined requirements were met by using digital control of a trough-line tuner via stepping motors and Fig. 7 shows a photograph of the resulting tuner. Separate stepping motors controlled the axial and vertical positions of an anodized aluminium slug within the trough of the tuner, via lead screws. By this means, source admittance values presented to the f.e.t. amplifiers

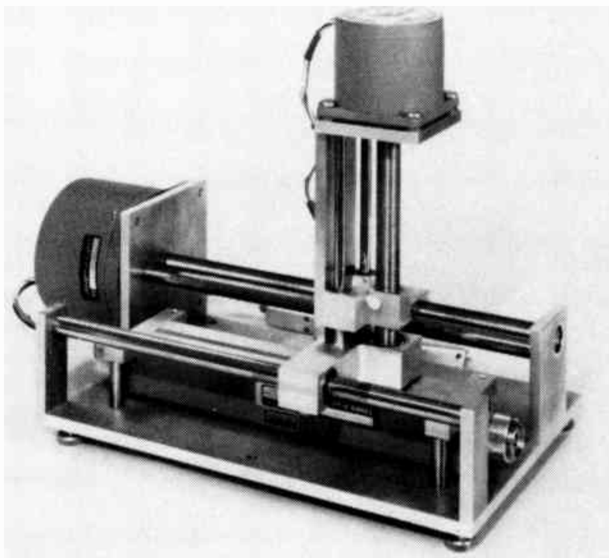


Fig. 7. Automatic slot-line tuner.

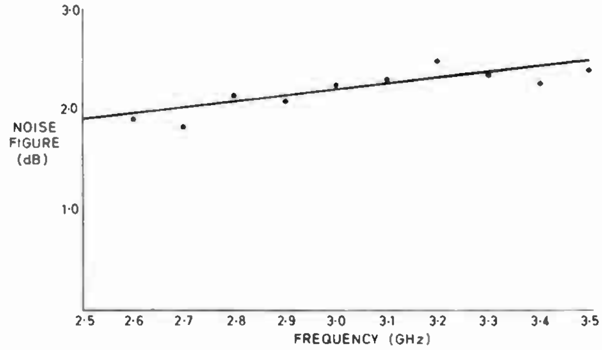


Fig. 8. GaAs f.e.t. noise figure versus frequency (Type P617A/P103/1; $V_{DS} = 5{\cdot}0$ V; $I_{DS} = 10$ mA).

could be controlled over all possible phase angles for reflection coefficients of up to 0·95.

The same interface unit illustrated in Fig. 6 was employed with separate data lines for the two motors, pulse polarity determining the direction of travel. Calibration of the tuner was effected using the ANA, adding an auxiliary sub-routine to the software for driving the tuner. The version shown in Fig. 7 operated from 1–10 GHz, the upper limit being extendable to 12 GHz by incorporating a slightly smaller tuning slug.

Having obtained full automation of the source admittance setting, data collection and processing, the role of the operator was simply to set up the frequency and bias values and to tune the output circuit of the device for maximum gain. It was necessary to perform the latter operation only once per frequency point, since varying bias conditions affected only slightly the matching at the load. Up to thirty different bias conditions could be required for each frequency of measurement and it was demonstrated that all could be accommodated without changing the load matching condition.

A typical measurement run involving the setting of eight source admittance values would take some 45 ms, most of this time being required for movement of the tuner, including return to the reference position.

5 Results

The measurements of devices were confined to GaAs f.e.t.s, because of their availability from the industrial sponsor, but the equipment could in principle be used for any two-port amplifying device, given appropriate biasing arrangements. There is no basic reason why the system could not be employed with bipolar transistors or even diode amplifiers (e.g. Gunn, impatt or trapatt types).

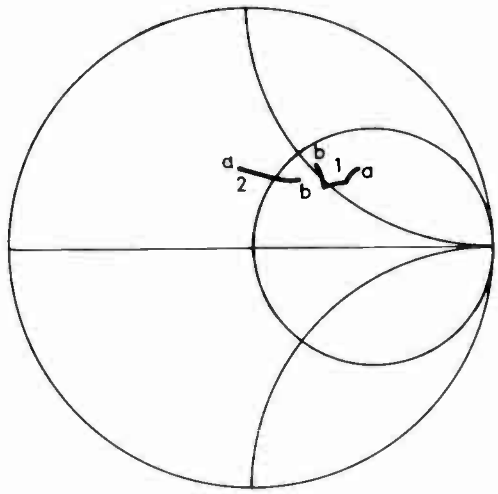


Fig. 10. Smith chart plots of optimum source impedance with frequency (curve 1) and drain current (curve 2).

$V_{DS} = 5{\cdot}0$ V $I_{DS} = 10$ mA	Curve 1	$f = 2{\cdot}5$ GHz at a 3·5 GHz at b
$V_{DS} = 5{\cdot}0$ V $f = 3$ GHz	Curve 2	$I_{DS} = 70$ mA at a 5 mA at b

A typical plot showing the way in which the minimum noise figure increases with frequency for a Plessey GaAs f.e.t. at fixed bias is shown in Fig. 8. The relationship between minimum noise figure and drain current for the same device is shown in Fig. 9. Here the frequency and drain bias were fixed and the drain current caused to vary via the gate bias, from saturated drain current to near 'pinch-off' (5 mA). In Fig. 10, curve 1 shows a Smith chart polar plot of optimum source impedance over the same frequency range and with the same bias condition as for Fig. 9, the normalizing value being 50 Ω. On the chart, curve 2 shows the variation of optimum source impedance for the same conditions as in Fig. 9. In Fig. 11 variations with drain-current of both minimum noise figure and noise resistance are shown, again for a fixed frequency and drain bias, but for a different device. The minimum noise figure occurs at around 15% of the saturated drain current, as before.

Although the above results were all obtained with

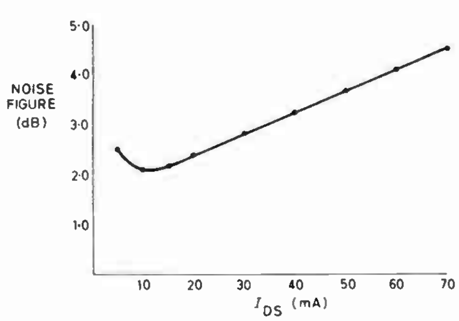


Fig. 9. GaAs f.e.t. minimum noise figure versus drain current (Type P617A/P103/1; $V_{DS} = 5{\cdot}0$ V; $f = 3{\cdot}0$ GHz).

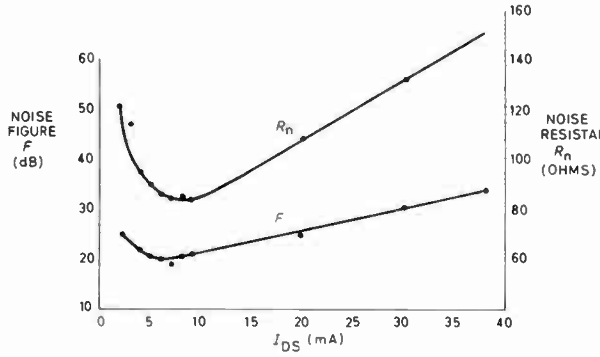


Fig. 11. GaAs f.e.t. minimum noise figure and noise resistance versus drain current (Type 106/7; $V_{DS} = 5{\cdot}0$ V; $f = 3{\cdot}0$ GHz).

the semi-automatic system, the fully automatic system showed effects of entirely similar nature.

6 Discussion and Conclusions

This work has demonstrated the feasibility and advantages of using an on-line computer to obtain full noise characterization of microwave devices, in particular GaAs f.e.t.s. A system embracing sophisticated hardware and software has been evolved, the development having commenced at a time when there was only one published work in this area and that limited to u.h.f.[4] The main attractiveness of the system lies in its ability to provide quickly the principal noise parameters as functions both of bias and frequency.

There is some scope for further improvement, particularly with regard to software, as the effects of certain second-order correction terms are not currently incorporated. For instance, image rejection at the mixer is not infinite and system reflections have a detectable effect, although 'off-line' examination has shown them to make small difference to the results. One desirable feature not yet incorporated is the provision of a graphical output on the display unit.

The full frequency capability of the present hardware at up to 12 GHz has still to be investigated. With the ever-pressing requirements for operation at still higher frequencies there is interest in developing a similar system to make reliable measurements of noise figure up to at least 40 GHz.

7 Acknowledgments

The authors wish to thank Mrs. C. A. Stoneman and A. J. Hume at Warwick University for computing assistance. The work was supported by Plessey (Research) Caswell Ltd., and by the Science Research Council.

8 References

1 IRE Sub-Committee 7–9 Noise, 'Representation of noise in linear twoports', *Proc. IRE*, **48**, no. 2, pp. 69–74, 1960.
2 Wait, D. F., 'Measurement of amplifier noise', *Microwave J.*, **16**, no. 1, pp. 25–29, 1973.
3 Friis, H. T., 'Noise figures of radio receivers', *Proc. IRE*, **32**, pp. 419–22, 1944.
4 Lane, R. Q., 'The determination of service noise parameters', *IEEE Proc.*, **57**, no. 8, pp. 1461–2, 1969.
5 Shurmer, H. V., 'A flexible microwave automatic network analyser system', *The Radio and Electronic Engineer*, **51**, no. 6, pp. 287–98, 1981.

Manuscript first received by the Institution on 23rd September 1981 and in final form on 25th February 1982
(Paper No. 2049/M128)

UDC 621.391.812.7: 621.396.93:
Indexing Terms: Simulators, Radio systems, mobile, Fading

A real-time fading simulator for mobile radio

J. R. BALL, B.Sc., M.Sc., C.Eng., MIEE*

SUMMARY

A test equipment for simulating the Rayleigh-distributed fading encountered in mobile radio is described. The fading is achieved by in-phase and quadrature modulation of the radio signal by two independent Gaussian noise signals. The noise formation and filtering are performed using a microprocessor for which the clock frequency can be varied to control the fade rate. The simulator has been designed to handle amplitude modulated signals and is being used in the development of s.s.b. mobile-radio receivers.

* *British Telecom Research Laboratories, Martlesham Heath, Ipswich IP5 7RE.*

1 Introduction

When developing or assessing mobile-radio equipment in the laboratory it is useful to be able to simulate the rapid fading which is a characteristic of the mobile-radio environment. This paper describes a fading simulator which accurately generates Rayleigh-distributed fading at rates up to a Doppler frequency of 150 Hz, which is equivalent to a vehicle speed of 50 m/s (112 miles/h) at a carrier frequency of 900 MHz. The simulator has been designed to operate at frequencies around 160 MHz, but it can be readily adapted to other frequencies up to about 600 MHz. This upper limit is imposed by the type of balanced modulators employed. Operation in 900 MHz radio systems is possible by using frequency translation following the simulator, or by operating at the first i.f. of the receiver.

2 Principle of Operation

The simulator uses the well-known technique in which the signal is split into two quadrature components which are independently modulated with low-frequency noise having a Gaussian amplitude distribution. When these two signal components are summed the resulting signal has a Rayleigh amplitude distribution and a uniformly distributed random phase angle. The method has been described previously,[1] and is shown schematically in Fig. 1.

2.1 Spectrum Shape

The shape of the fading spectrum produced by the simulator is determined by the low-pass filters which follow the noise sources.

The fading spectrum appropriate to mobile radio has been derived elsewhere[2,3] and is generally assumed to have an energy spectral density given by:

$$S(f) = \begin{cases} \dfrac{E^2}{2\pi f_D}\left[1 - \left(\dfrac{f}{f_D}\right)^2\right]^{-\frac{1}{2}}, & f \leqslant f_D, \\ 0, & f > f_D, \end{cases} \qquad (1)$$

where f_D is the Doppler frequency appropriate to the vehicle speed and E is the r.m.s. signal strength.

The derivation of equation (1) assumes a large number of signal components of constant amplitude arriving at the vehicle with uniformly distributed angles of arrival, each component having a Doppler frequency shift proportional to the cosine of the arrival angle relative to the direction of motion.

To see how the spectral shape of equation (1) occurs, consider the signal which arrives from direction θ, and within the small angle $\delta\theta$ (Fig. 2). The frequency offset will be $f = f_D \cos\theta$. Energy spectral density is proportional to dE/df, which in the case of uniformly distributed scatterers is proportional to $|\partial\theta/df|$.

Hence

$$S(f) \propto \left|\frac{d}{df}\left(\cos^{-1}\frac{f}{f_D}\right)\right| = \left[1 - \left(\frac{f}{f_D}\right)^2\right]^{\frac{1}{2}}$$

This results in a spectrum which is sharply bounded by $\pm f_D$. However, in practice these signal components will

0033–7722/82/100475+04 $1.50/0

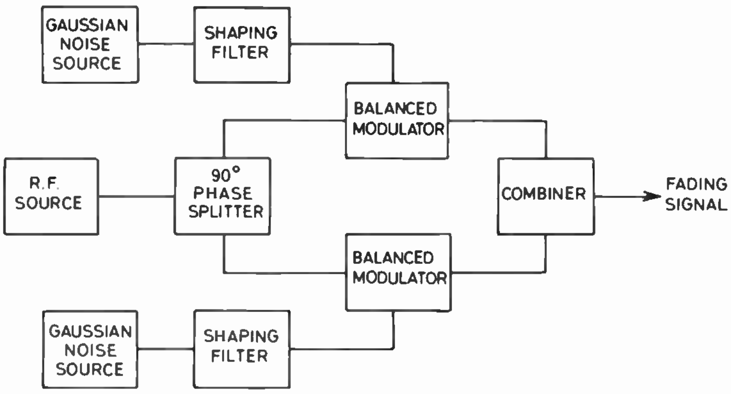


Fig. 1. Basic Rayleigh fading simulator.

be amplitude modulated in a random manner as the position of the vehicle relative to the scatterers changes. This modulation is not included in the above derivation; it can be expected to produce a spreading of the spectrum given by (1). No reports of field measurements with sufficient resolution to detect this spreading have been found, and so a value had to be chosen. The random nature of the process suggests a Gaussian modulation which would result in a similarly shaped spreading in the frequency domain.

Gaussian spreading with a standard deviation of $0{\cdot}2f_D$ was found to give a spectral shape not dissimilar to the spectrum chosen in Ref. 1 and so was adopted. The resulting spectrum is shown in Fig. 3.

The low-pass filtered noise sources of Fig. 1 are required to produce two independent noise-like waveforms having Gaussian amplitude distributions with zero mean and with a spectrum of the form shown in Fig. 3.

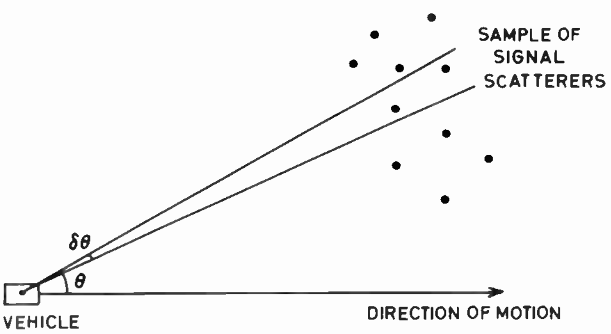


Fig. 2. Derivation of fading spectrum.

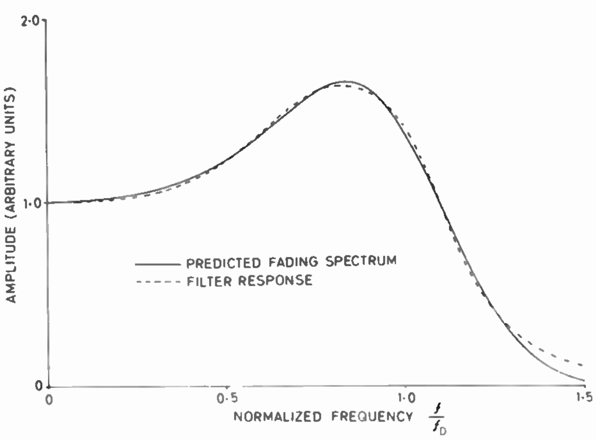


Fig. 3. Fading spectrum and filter response.

3 Practical Implementation

The simulator was designed to cover a range of fading rates in order to simulate various vehicle speeds at either v.h.f. or u.h.f. This required a range of Doppler frequencies from about 0·15 Hz up to 150 Hz. Although this range could be achieved by using a large number of separate filters, some form of tunable filter was clearly indicated. The solution adopted uses digital filters implemented in an Intel D2920 Analog Signal Processor. By varying the processor clock frequency the filters can be tuned without changing the shape of their frequency response. The noise sources are also implemented digitally in the D2920 using pseudo-random binary sequences (p.r.b.s.).

3.1 Noise Generators

It is well known that a long p.r.b.s. can be low-pass filtered and used as a noise source. However, it is not generally appreciated that a filtered p.r.b.s. does not always have a statistically good amplitude distribution.[4] In particular, trinomial sequences (produced from a shift-register generator with only two feedback taps) produce significantly skew amplitude distributions when filtered.

The two p.r.b.s. used in the simulator are of length $2^{19}-1$ and $2^{24}-1$ respectively and were selected from a published table of primitive polynomials.[5] Both require four feedback taps. The register lengths of 19 and 24 bits respectively are convenient for the 25-bit word length of the D2920. The effective clock rate of the p.r.b.s. generators is the cycle time of the program in the D2920. The program for both filters and p.r.b.s. generators occupies only 96 program steps and is repeated twice during the 192-step cycle of the processor, which takes 125 μs at its maximum clock rate. The maximum p.r.b.s. clock rate is therefore 16 kHz, giving repeat times of 33 s and 1048 s for the two p.r.b.s.

3.2 Low-pass Filters

A low-pass filter having the desired frequency response was designed with the aid of a curve-fitting program run on a desk-top computer. A reasonably good fit was obtained from a five-pole filter having a transfer function given by:

$$\frac{1}{H(s)} = (0{\cdot}897s^2+0{\cdot}31s+1)\times \times(1{\cdot}543s^2+0{\cdot}841s+1)(1{\cdot}944s+1). \quad (2)$$

The response of this function is shown in Fig. 3. It was converted to sampled digital form using the matched z-transform[6] and coded for the D2920. The filter parameters were scaled to give $f_D = 150$ Hz when running at a sampling rate of 16 kHz.

3.3 Balanced Modulators

The simulator is required to handle amplitude-modulated signals. An earlier version of the simulator had been provided with diode ring modulators, but it was found that these performed poorly when handling signals of varying amplitude. It would appear that this type of modulator is unsuitable when both the r.f. and Gaussian modulating signals are of low and comparable levels. Under these conditions the modulator behaves more like a limiter. This effect is not normally apparent in other diode ring applications where either one or the other input signal is always at a high level.

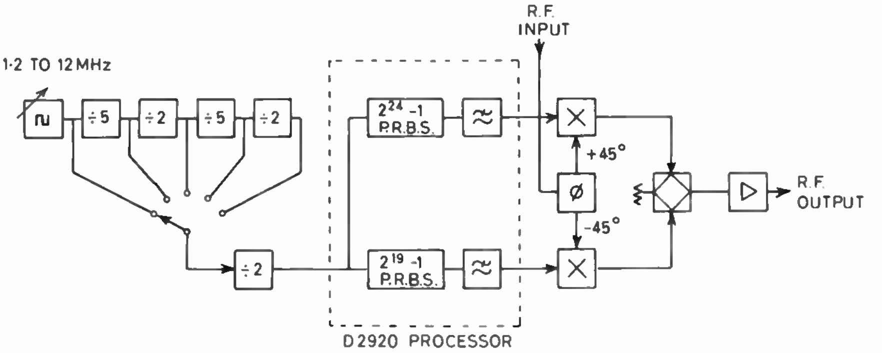


Fig. 4. Block diagram of the simulator.

The ideal modulator for this application would be a true four-quadrant multiplier. Such performance is approached by transconductance multipliers employing transistor long-tailed pairs, and one such device (the Mullard TDA 0820) was chosen for the simulator. Although the usable frequency response of this device extends only to some 600 MHz, use on 900 MHz radio systems is possible by using frequency translation or by operating at the first i.f. of the receiver.

The incoming r.f. signal is split into two components in phase quadrature before reaching the modulators and is subsequently recombined in a 3 dB resistive combiner. Balun transformers are used in the phase splitter and to precede and follow the two modulators. These transformers are wound on small ferrite beads (FX 1898) in the manner described by Ruthroff.[7]

4 Performance

A schematic diagram of the complete fading simulator is shown in Fig. 4. The processor clock can be set to any frequency between 6 kHz and 6 MHz, giving fading rates equivalent to a Doppler frequency range of 0·15 to 150 Hz. The r.f. bandwidth of the simulator is primarily determined by the 90° phase splitter; departure from its design frequency results in relative phase and amplitude errors in the two quadrature channels. In practice these errors are found to be small over a half-octave frequency range centred on the design frequency of 160 MHz.

The amplitude distributions of the filtered noise waveforms were checked with the aid of a computer linked to a d.v.m. This enabled a large number of readings to be accumulated and displayed in the form of a histogram. A typical result is shown in Fig. 5, illustrating a good approximation to a Gaussian distribution.

The r.f. transfer characteristic of the simulator can be measured with the aid of a network analyser. A long exposure photograph of the analyser polar display is shown in Fig. 6. The symmetry of the display confirms the amplitude balance and orthogonality of the two channels in the simulator. Finally, a magnitude/time display obtained from a spectrum analyser (Fig. 7) shows the characteristic shape of Rayleigh fading.

5 Conclusions

The equipment described in this paper accurately simulates the Rayleigh distributed fading which is characteristic of the mobile-radio environment. The principle of operation has been described elsewhere, and involves quadrature modulation of the radio signal by two independent low-frequency noise sources of defined frequency spectrum. Digital generation and filtering of the noise signals is used, and enables the simulated fading rate to be directly controlled by varying the processor clock frequency. Fading rates equivalent to a Doppler frequency range of 0·15 Hz to 150 Hz are obtainable. The use of transconductance multipliers for

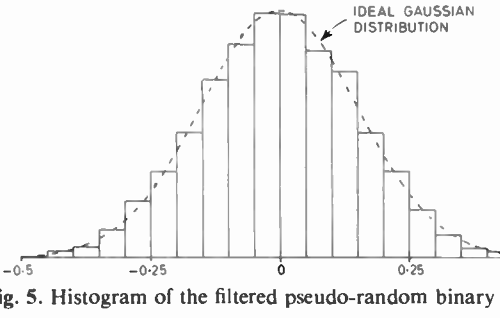


Fig. 5. Histogram of the filtered pseudo-random binary sequence.

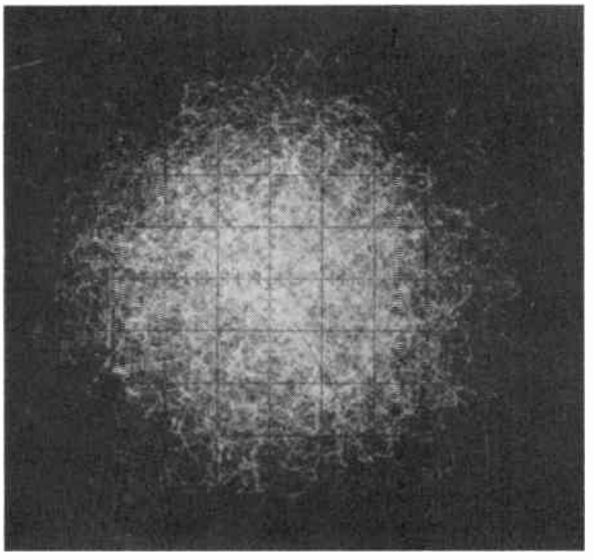


Fig. 6. Fading signal. Polar display obtained from a network analyser (1 minute exposure).

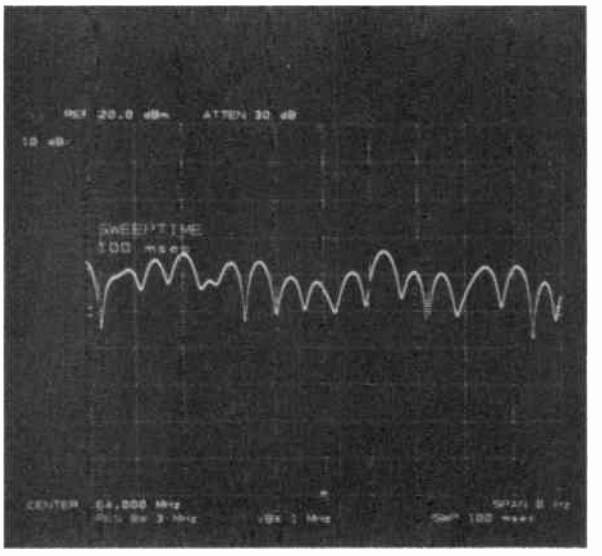


Fig. 7. Fading signal. Magnitude/time display obtained from a spectrum analyser.

the r.f. modulators overcomes a non-linearity problem previously experienced with diode ring modulators, and enables the simulator to be used with amplitude-modulated signals. The simulator is being used in the development of a.g.c. and a.f.c. systems for s.s.b. mobile-radio application.

6 Acknowledgments

The author wishes to thank the Director of Research of British Telecommunications for permission to publish this paper.

7 References

1 Arredondo, C. A., Chriss, W. H. and Walker, E. H., 'A Multipath fading simulator for mobile radio', *IEEE Trans. on Vehicular Technology*, VT-22, no. 4, pp. 241–4, November 1973.

2 Clarke, R. H., 'A statistical theory of mobile-radio reception', *Bell Syst. Tech. J.*, 47, pp. 957–1000, July/August 1968.

3 Jakes, W. C. Jr., 'Microwave Mobile Communications', chap. 1 (John Wiley, New York, 1974).

4 Hurd, W. J., 'Efficient generation of statistically good pseudo-noise by linearly interconnected shift registers', *IEEE Trans. on Computers*, C-23, no. 2, pp. 146–52, February 1974.

5 Watson, E. J., 'Primitive polynomials (mod 2)', *Mathematics of Computation*, 16, no. 79, pp. 368–9, July 1962.

6 2920 Analog Signal Processor Design Handbook, Intel Corporation, 1980.

7 Ruthroff, C. J., 'Some broadband transformers', *Proc. IRE*, 47, pp. 1337–42, August 1969.

Manuscript first received by the Institution on 7th January 1982, and in final form on 24th March 1982
(Paper No. 2050/Comm 348)

UDC 534–8 : 616–076 : 620.179.1
Indexing Terms: Ultrasonic waves, Ultrasonic equipment, Ultrasonic applications, Microscopic examination, Non-destructive testing

Recent developments in scanning acoustic microscopy

D. A. SINCLAIR, Ph.D.,*
I. R. SMITH, Ph.D.*
and
H. K. WICKRAMASINGHE, Ph.D.*

SUMMARY

The operating principles of the Quate–Lemons scanning acoustic microscope and some recent developments in the detection and interpretation of acoustic images are reviewed. In particular the measurement of elastic constants using the microscope, which may ultimately provide a new high resolution technique for material characterization, is demonstrated.

* *Department of Electrical and Electronic Engineering, University College London, Torrington Place, London WC1E 7JE.*

1 Introduction

The Scanning Acoustic Microscope (SAM), first demonstrated by C. F. Quate and R. A. Lemons at Stanford University in 1973,[1] will shortly become commercially available and so it is appropriate to review the principles and performance of this novel instrument. The concept of a microscope using sound rather than light was first considered by Sokolov in 1949.[2] There are two main advantages in such an instrument. First, the images are formed from the interaction of sound waves with the specimen, and so contrast in acoustic images relates to the mechanical properties of the specimen. Experience has shown that acoustic micrographs can have high contrast for specimens that appear uniform or opaque in the optical microscope; the complex and sometimes lengthy staining procedures common in optical or electron microscopy are not required. Second, the spatial resolution of an imaging system depends upon the wavelength λ of the illuminating radiation. In a well-designed microscope it is possible to resolve points $0{\cdot}6\lambda$ apart. Thus the greatest resolution in an optical microscope using green light is 0·3 µm. The speed of sound wave propagation is very much less than the speed of light and hence only modest acoustic frequencies are necessary to obtain comparable optical and acoustic wavelengths. Current developments in SAM instrumentation should provide resolutions a factor of 5 to 10 times better than the optical limit.

Many techniques for acoustic microscopy have been proposed[3–5] but the Quate–Lemons SAM[6] is unique in its image quality and resolution. The use of mechanical scanning and an on-axis focusing lens has led to a wide flexibility of operation. A number of the techniques in optical microscopy find their counterparts in the SAM, such as phase contrast, differential phase contrast, dark field, stereo-microscopy and double-exposure imaging. We will review these and illustrate them with images from our laboratory.

The commercial instruments are likely to have similar resolution and field of view to the best optical microscopes and yet this does not represent the ultimate achievable performance of the SAM—already it is clear that 50 nm resolution should be possible. We will examine the factors which limit imaging performance and illustrate our discussion with the design parameters of our high pressure gas microscope.

Although the creation of a higher resolution microscope is an important part of the present research effort in acoustic microscopy, a number of applications have emerged which do not solely rely upon seeing the ultra-small. Because images are scanned sequentially, they are simply digitized and this, together with the possibility of coherent detection, permits several methods of analysis. We are working on schemes by which the mechanical properties of a specimen may be computed from its acoustic image, thereby producing a microscopic map of its elasticity and density. In particular we have developed a technique in which the structure and orientation of anisotropic materials may be revealed. Similarly, the use of sound waves permits interior imaging for non-destructive evaluation applications such as bond testing and crack detection. In these applications even modest resolutions may yield useful results.

0033–7722/82/100479+15 $1.50/0

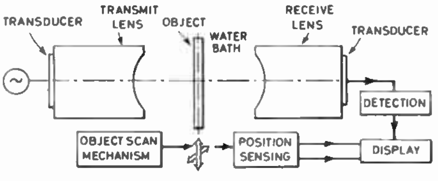
2 The Quate–Lemons Scanning Acoustic Microscope

The geometry of a transmission SAM is shown in Fig. 1. Two identical lens assemblies are rigidly mounted and separated by a coupling fluid. On the rear of each sapphire lens crystal is a piezoelectric thin film transducer.[7] The radio-frequency input signal is applied to the transmitting lens transducer, and so a beam of longitudinal waves is launched into the sapphire rod. This propagates (without significant loss) to the far side of the rod, where it is incident upon the lens—a simple spherical concave surface ground into the sapphire. Because of the large ratio between the acoustic velocity in sapphire (11 100 ms^{-1}) and that in the coupling fluid (in the case of water 1500 ms^{-1}) the sound waves are strongly refracted by the lens. Rays incident upon the lens emerge close to the direction of the lens surface normal and are focused at a point slightly in front of the lens centre of curvature.

The receiving lens, which is confocal with the transmitter, collects and recollimates the energy, and a second transducer converts it back into an electromagnetic signal, which is detected and amplified by a conventional radio receiver. The specimen is mounted on a thin mylar film placed in the focal plane of the two lenses. Thus the receiver output is proportional to the transmittance of the specimen in the narrow focal region illuminated. In order to form a complete image, the specimen is mechanically scanned in a raster pattern normal to the lens axis. The beam of a storage oscilloscope is brightness-modulated by the detected signal from the receiving lens and the beam is deflected in synchronism with the specimen. Alternatively the image may be directly recorded by a digital frame store and displayed on a v.d.u.

The resolution of the acoustic microscope is determined by the width of the acoustic beam at the focus. The only lens defect for this on-axis configuration is spherical aberration and herein lies perhaps the most remarkable feature of the SAM. Because the velocity ratio between the lens and the coupling fluid is very large, the effects of spherical aberration are negligible compared with diffraction. Thus the spherical acoustic lens can be designed with a wide aperture (*f*1 or smaller) and thereby produce a diffraction limited focal spot only one wavelength wide. This beamwidth determines the size of the smallest resolvable feature. Since the maximum velocity ratio in optical systems is 2 : 1, it is necessary to use complex compound lenses in order to achieve comparable aberration-free performance.

The factors which affect resolution are the acoustic frequency, which should be high, and the propagation velocity in the coupling fluid, which should be low for a short wavelength. The maximum frequency possible is limited by the absorption of sound waves in the coupling fluid, which generally increases with the square of frequency. In water at 1 GHz and 20°C, absorption is



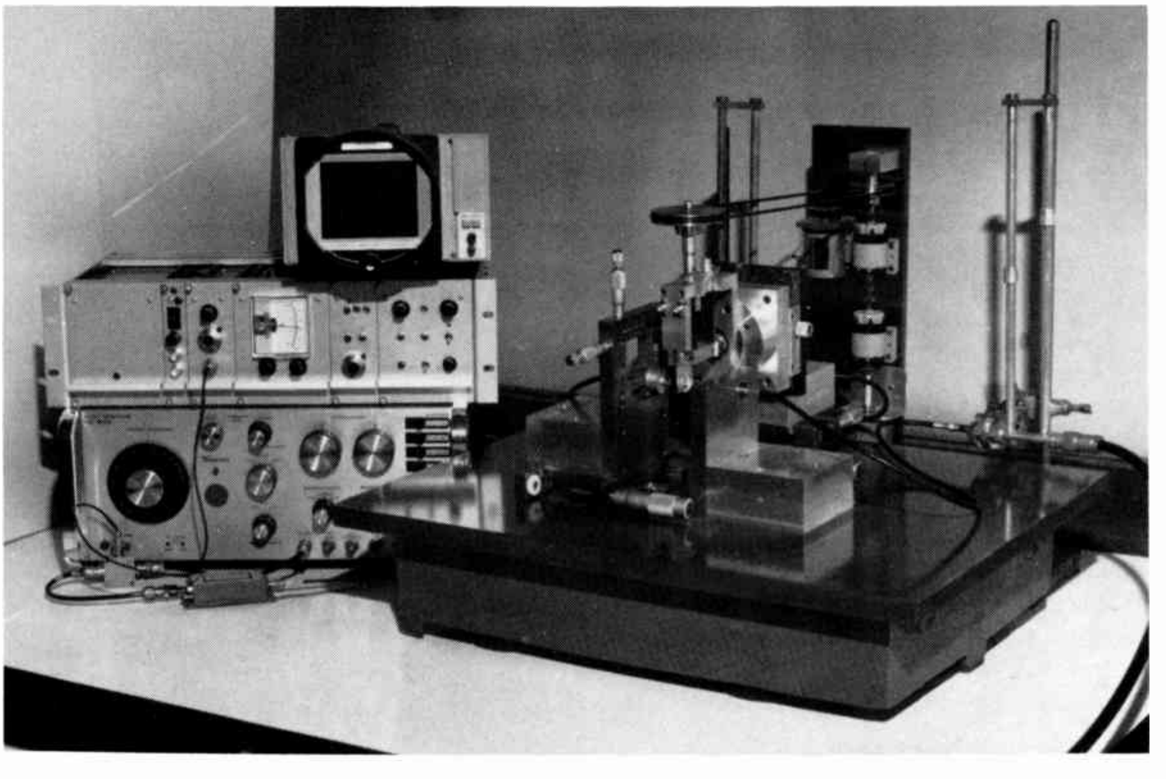
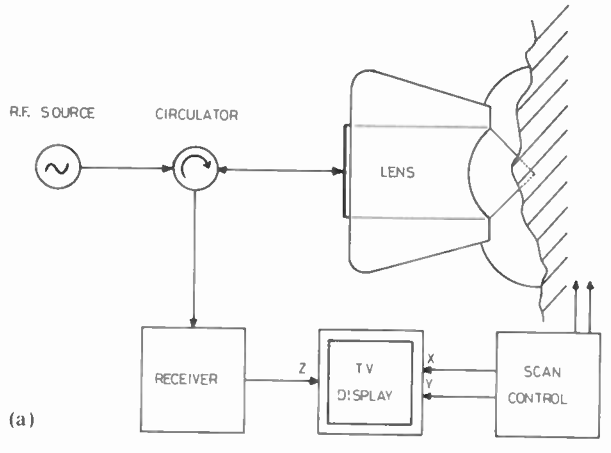


Fig. 1. Transmission scanning acoustic microscope. Block diagram and component assembly—the acoustic lens assembly and scanning mechanism is on the right and the r.f. source, detector and image display are on the left.



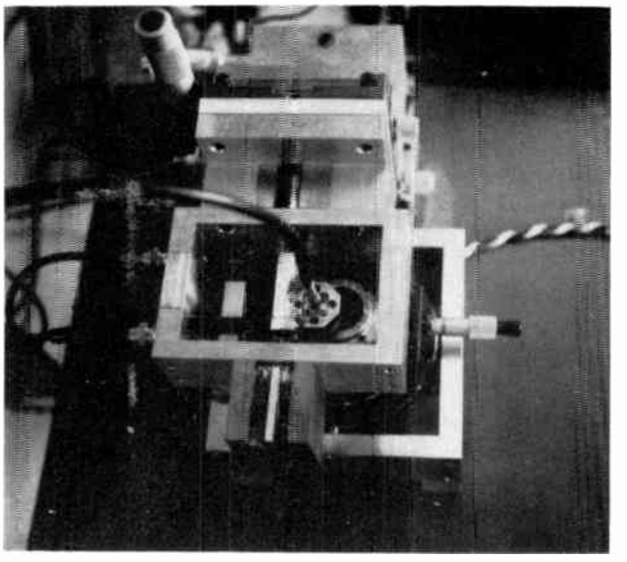

(b)

Fig. 2. Reflection scanning acoustic microscope.
(a) Block diagram.
(b) Acoustic and scanning component assembly.

220 dB/mm and so the lens radius must be very small (about 100 µm) for detectable energy levels to reach the receiving lens. Thus the potential resolution of the instrument depends upon the velocity and absorption of the coupling fluid. At Stanford University a SAM operating at 3·5 GHz using hot water as the coupling medium has been demonstrated,[8] giving comparable resolution to that which can be achieved optically. As we shall see later, water is by no means the best coupling fluid.

The magnification of the SAM is simply the ratio of the scan size to that of the display. Since the scan mechanism is usually electromechanical, the magnification is electronically variable. Similarly, there is no inherent limit to the field of view, which can be as large as the scanner permits.

Because of the generally large difference in acoustic impedance (the product of density and velocity) between the lens crystal and the coupling fluid, much of the sound energy incident upon the lens is reflected. This reflection loss can be reduced by the use of a quarter-wavelength matching layer. Even so, reverberation within the lenses is a significant factor, and the microscope is generally used with pulsed rather than c.w. excitation. Time gating is then employed to select the wanted signal. Because sharply focused sound beams are used, the depth of focus is comparable with the transverse spatial resolution and is unaffected by the pulse length (since the latter is usually much greater).

Since the acoustic wave is generated by piezoelectric transducers, it is possible to use a coherent detector to measure both the amplitude and phase of the microscope output. This is in contrast to the conventional optical microscope which records intensity variations—although there are parallels between phase detection in the SAM and Zernike phase contrast[9] in optical microscopy. In the SAM, phase variations are detected by comparing the output signal with an electrically derived phase reference.[10,11] The significance of coherent detection is that it permits *two* independent measurements, either in transmission or reflection, at each image point. As described later, this additional information is of considerable help in deducing the properties of the specimen.

The transmission geometry shown in Fig. 1 requires precise alignment of the focal points of the two lenses, as well as a thin specimen. The alignment problem becomes prohibitive for focal spot sizes below 1 µm and so the more common arrangement for the highest resolution instruments is the reflection SAM (Fig. 2). The single lens transmits a short (100 ns) pulse at the desired acoustic frequency, and receives the energy reflected by the specimen. A ferromagnetic circulator separates the transmission and reception paths and an image is scanned in the normal way. The pulses must be sufficiently short to discriminate the energy reflected at the lens interface from the delayed energy reflected by the specimen. Thus there is a minimum lens radius depending upon the transducer bandwidth.

Figure 2(b) shows a complete reflection SAM used with a water-coupled 120 µm lens suitable for operation at 1–1·5 GHz with 1 µm resolution. The lens is scanned over the static specimen, driven in one axis by a loudspeaker scanner and in the other by a servomotor-driven micrometer. The scan time is about five seconds. A differential micrometer allied to a piezo-electric pusher is used to focus the instrument precisely.

3 Imaging of Biological Samples

A principal advantage of the acoustic microscope is its ability to image unstained biological materials with high contrast. Figure 3 shows an intensity image of human red blood cells using a water-coupled transmission SAM. The images demonstrate the generally high contrast which is found in many biological materials without the need for the complex staining procedures often used in optical microscopy. The cells are 7 µm in diameter and 2 µm thick at the edges, 1 µm in the centre. Since small concentrations of nutrients will not affect the acoustic performance of the coupling fluid, it is possible to culture

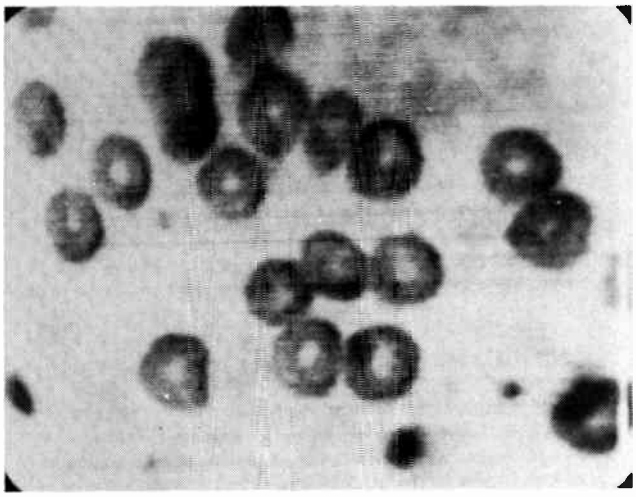


Fig. 3. 900 MHz transmission SAM intensity image of human red blood cells—these are typically 7 μm in diameter.

cells and organisms in the SAM using a temperature-controlled specimen holder. Thus there is the promise of higher resolution with perhaps fewer artifacts using the SAM. The peak acoustic intensity at the focus is about 30 W/cm^2 but because of the low duty cycle (0·1%) and the scanned nature of the image formation, the effective mean power level is less than 1 mW/cm^2. This level of radiation does not have any apparent effect on biological specimens.

4 Differential Phase-contrast Acoustic Microscopy

Phase-contrast images obtained using conventional coherent detection[10,11] are accurate to approximately 1°, depending upon the dynamic range of the instrument. The limit to phase accuracy arises from the fact that we are measuring the phase variation over an acoustic path of several hundred wavelengths, although we associate the measured change with the specimen, in general only one wavelength thick. Any thermal or vibrational changes in the microscope can cause phase shifts far in excess of those created by the specimen. One solution to this problem is to pass the reference beam through an identical close-coupled acoustic path to the microscope, so compensating for specimen-independent fluctuations.[12] A more sensitive phase detector may now be used, with consequent improvements in phase accuracy.

The technique of differential interference (Nomarski) contrast is highly successful in optical microscopy, and we have developed a similar system for the SAM[13] (Fig. 4). In this we compare the phases of the responses of adjacent points on the specimen. The Figure shows a transmission instrument although the technique is easily applied in reflection. A conventional lens assembly illuminates the specimen with a focused beam of longitudinal acoustic waves. The energy transmitted by the specimen is collected and recollimated by the receiving lens, which has a circular transducer split into two equal semicircular elements. The voltage developed by each half is separately limited and the phase difference between the two is detected by a phase bridge. The specimen is mechanically scanned in a plane close to, *but not in*, the confocal plane, and an image is raster-scanned in the normal way.

The significance of the defocus distance becomes clear if we consider the receiving lens sensitivity function. In the focal plane the two halves of the lens have equal amplitude but oppositely-tilted phase distributions. As we defocus closer to the lens, the two focal distributions separate into spatially distinct off-axis foci—our image is formed from the phase difference between the two spots, and so represents the phase gradient. The actual gradient range will depend upon the degree of spot separation and hence upon the defocus distance. Figure 5 shows plots of the receiver lens sensitivity function in our prototype microscope, (a) in the focal plane, and (b) in a plane six wavelengths closer to the lens, clearly demonstrating the separation of the two foci. The relatively slow rate of separation is consistent with the small aperture lenses we were using—with more conventional wide aperture lenses the distance for separation would be smaller.

Because the acoustic paths are nearly identical we achieve almost exact phase compensation between the two beams. Figure 6 shows a differential image from our prototype microscope of a notch cut in an aluminium alloy plate showing strong interference of the propagating waves in the plate. These are detected with greater sensitivity using the differential phase microscope. We are extending the technique to map

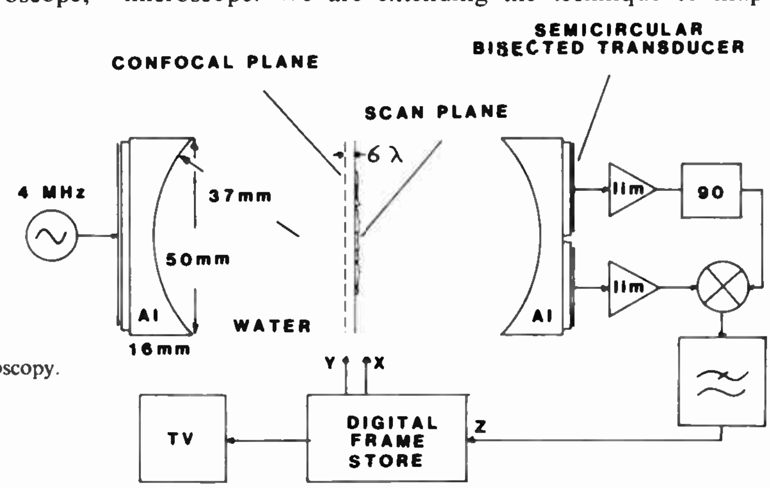


Fig. 4. Geometry for differential interference acoustic microscopy.

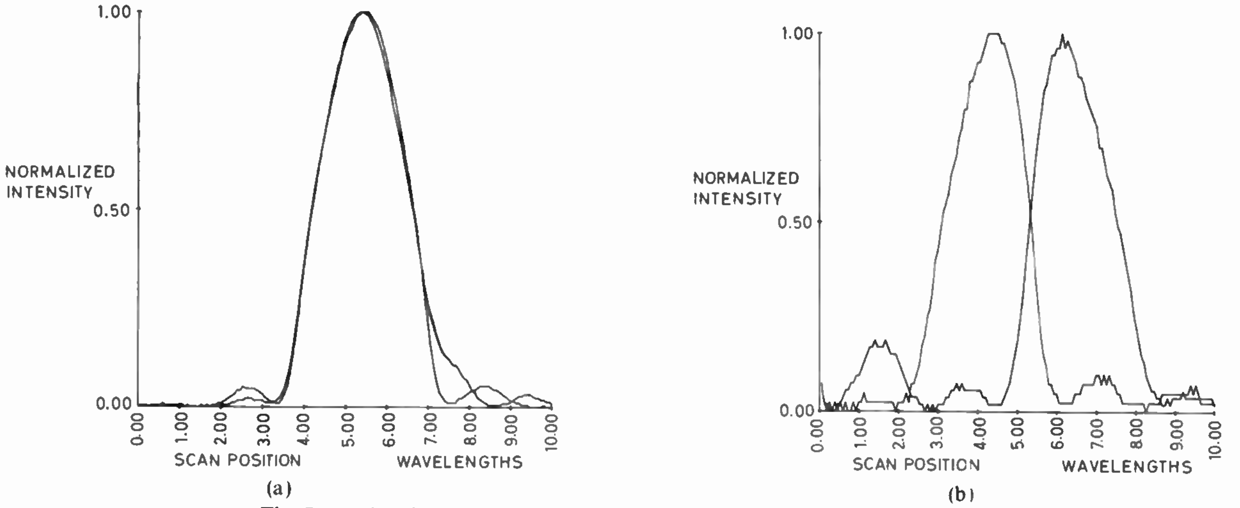


Fig. 5. Receiver lens function for differential intereference acoustic microscope. (a) In lens focal plane. (b) In a plane six wavelengths closer to the lens. Frequency 4 MHz.

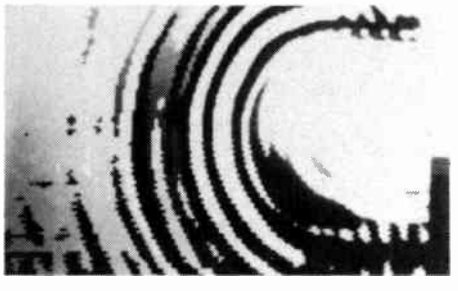


Fig. 6. 4 MHz differential acoustic microscope image of a notch cut in an aluminium plate—the field of view is 10 by 6 mm.

acoustic velocity fields, both for human tissue characterization as well as for imaging stress fields surrounding cracks in structural materials. We expect our images to show much finer variations than previously.

5 Dark Field Acoustic Microscopy

Low-contrast, highly transmissive objects pose certain problems when imaged in either conventional optical or acoustic microscopes. The main difficulty is that the wanted contrast is a small signal superimposed on a large d.c. component due to the overall transmittance of the objects. Off-axis illumination can be used to remove this large signal offset in an optical microscope and early versions of dark-field SAMs used a tilted lens geometry to achieve the same effect.[14] Such systems were difficult to align since in the absence of a diffracting object there was no microscope output that could be used to indicate the correct focal alignment.

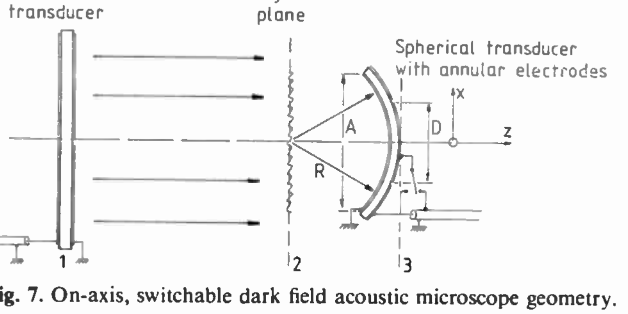


Fig. 7. On-axis, switchable dark field acoustic microscope geometry.

We have developed an on-axis system,[15,16] shown in Fig. 7, which may be electronically switched between dark and bright field operation. A plane wave source illuminates the object and the transmitted field is detected by a spherical transducer with annular electrodes. A switch may be used to isolate the central electrode. The object is scanned past the focal region of the spherical transducer to form an image in the normal way. When the central region of the spherical transducer is connected, the system is effectively a conventional SAM with only one lens. The angular sensitivity of the spherical transducer is simply a scaled form of its electrode pattern. When the central region of the transducer is disconnected, it is insensitive to on-axis plane waves. It is these waves that would produce the large d.c. component in the microscope output—by disconnecting the central transducer electrode this is prevented from appearing in the image. Only the small contrast variations due to the higher spatial frequencies incident upon the transducer are detected and, in the absence of the d.c. component, this small amount of contrast can be expanded to fill the full display dynamic range.

Figure 8 illustrates line scans of a $4\lambda/3$ diameter wire taken at 2·5 MHz ($\lambda = 0{\cdot}6$ mm) with a 24 mm radius, 24 mm aperture PZT4A transducer. Careful selection of the electrode dimensions is necessary to provide good zero-order suppression. In this case 20 dB was achieved. The sidelobes in the point spread function of the system are increased in the dark field mode and this is consistent with the use of what is effectively an annular aperture receiver.

Figure 9 shows bright and dark field images of a section of pig muscle with a band of fatty tissue running through the middle. Comparing bright and dark field images permits the identification of the diffractive areas of the tissue. Regions of negligible diffraction show up as dark regions in the dark field image. The location of relatively uniform areas is important since it is in those areas that we can make a more confident estimate of the tissue elastic constants.

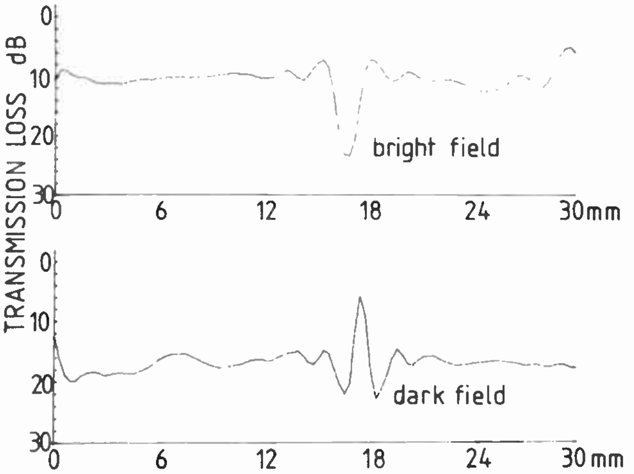


Fig. 8. Line scans of a $4\lambda/3$ diameter wire taken with acoustic microscope geometry of Fig. 7 (operating at 2·5 MHz).

scan mechanisms routinely employed in the SAM. Figure 11 shows phase images of onion cells taken with a 150 MHz transmission SAM (resolution 10 μm).[11] Particular care was taken in the experiment to minimize spurious effects such as phase drift in the system due to temperature variations. The images show several cells before and after immersion in a saline solution. Subtraction of the two images shows that substantial changes occurred in the cells. It is known that the contents of the cell osmotically contract to a much smaller volume when the cells are immersed in concentrated saline. The apparent division of the cells into light and dark areas in the saline image can be attributed to regions filled with saline and regions containing the remaining cell contents. The acoustic properties of the cell are changed by the presence of the saline and an increase in acoustic velocity of $2{\cdot}5 \pm 1{\cdot}5\%$ was measured in the interior of the cell. The present example is a simple demonstration of the double exposure technique. We feel that, allied with the techniques of elastic constant measurement described below, this will prove a powerful tool for examining growth mechanisms in cells and tissues.

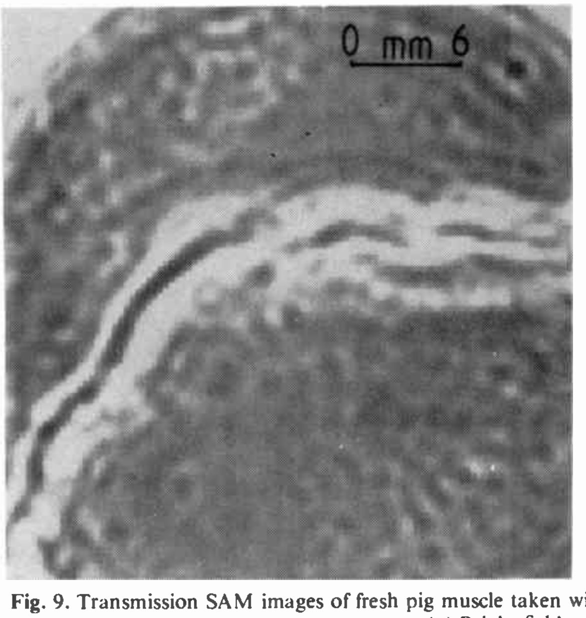


Fig. 9. Transmission SAM images of fresh pig muscle taken with the acoustic microscope geometry of Fig. 6 (operating at 2·5 MHz). (a) Bright field mode. (b) Dark field mode.

The extra sensitivity of dark field microscopy is also useful in detecting point defects in non-destructive testing applications. Figure 10 illustrates a non-uniformity in a butt weld between two 4 mm steel plates. The weld itself is visible due to the local elastic variations caused by the heating in the welding process, and a defective region (arrowed) is clearly resolved.

6 Double Exposure Techniques

There is a range of imaging applications in which the main interest is centred on any changes that occur in the sample due to certain stimuli, e.g. the growth of a cell in nutrient, the extension of a crack under stress. Due to the serial nature of image formation the acoustic microscope lends itself particularly well to digital storage and processing of pictures. It is therefore a relatively easy task to record several images of a specimen over a period of time for later comparison. Precise registration is ensured between images because of the high precision

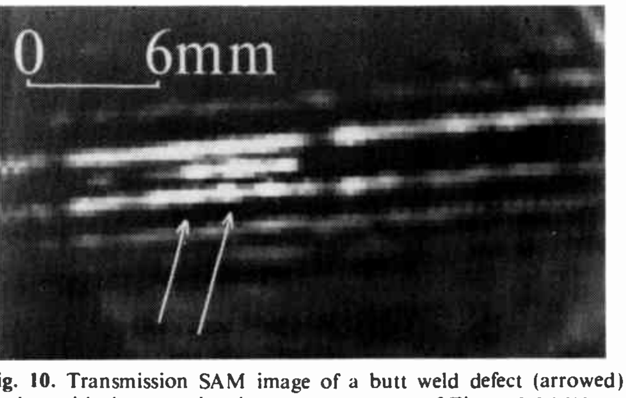


Fig. 10. Transmission SAM image of a butt weld defect (arrowed) taken with the acoustic microscope geometry of Fig. 6. 2·5 MHz.

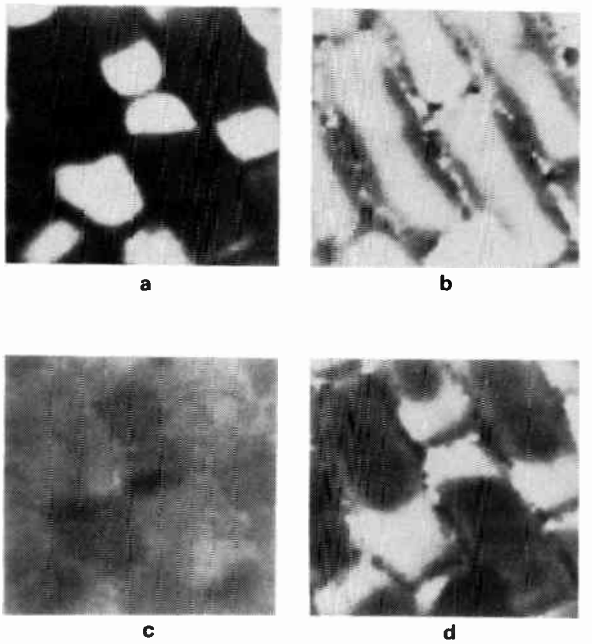


Fig. 11. 150 MHz transmission SAM images (250 by 250 μm) of onion cells showing recorded phase (after Bennett[11]). (a) Cells immersed in a saline solution. (b) Cells immersed in water. (c) Control subtraction of two frames repeated without change indicating total system noise level. (d) Difference between (a) and (b) showing regions of change due to osmosis.

7 Acoustic Microscopy of Elastic Constants

7.1 Paraxial Theories

The use of ultrasonic B-scan pulse-echo techniques for examining the interior of the human body is now routine in clinical diagnosis. However, there still remains much fundamental data to be gathered about the nature of acoustic propagation in human tissue. The SAM is an attractive tool for the quantitative investigation of the viscoelastic properties of *in vitro* tissue samples. The main problem to be solved is the derivation of expressions that relate the SAM amplitude, A, and phase, ϕ, images to the object properties of thickness, d, velocity, v, and impedance, z. In the analysis here the object velocity and impedance are normalized to those of the lens-object fluid coupling medium. In a simple paraxial theory applicable to small aperture lenses ($>f2$), Bennett[17] has shown that, at least for soft tissues ($1 < n < 4$, $1 < z < 3$):

$$V = \frac{kd}{\pm\cos^{-1}\left(\dfrac{\cos\phi}{A}\right) \pm 2\pi m} \quad (1)$$

$$Z = \frac{\sin\phi \pm \sqrt{1-A^2}}{\sqrt{A^2-\cos^2\phi}} \quad (2)$$

where k is the wavenumber in the fluid couplant and m is an arbitrary integer. These equations essentially describe plane wave propagation in a loss-less transmission line. There are many solutions therefore for a given image A and ϕ and it is necessary to have some *a priori* target values for the object velocity and impedance before these can be uniquely determined.

Figure 12 shows amplitude (a) and phase (b) images for a 450 μm thick slice of normal fixed human liver imaged at 11 MHz in a transmission SAM. Figures 12(c) and (d) show the velocity and impedance maps deduced from these images according to equations (1–2). The measured velocity ranges from 1·05 to 1·09 and the impedance from 0·50 to 1·48. While the former is in good agreement with macroscopic measurements in the literature,[18] the latter seems an excessively broad range. Our current efforts are concerned with selecting the properties of the coupling medium to give optimum accuracy. The measurement is sensitive to thickness variations as well as non-uniformities in the tissue section on a scale comparable to the microscope beamwidth. These factors may account for the large impedance spread measured and may be eliminated as

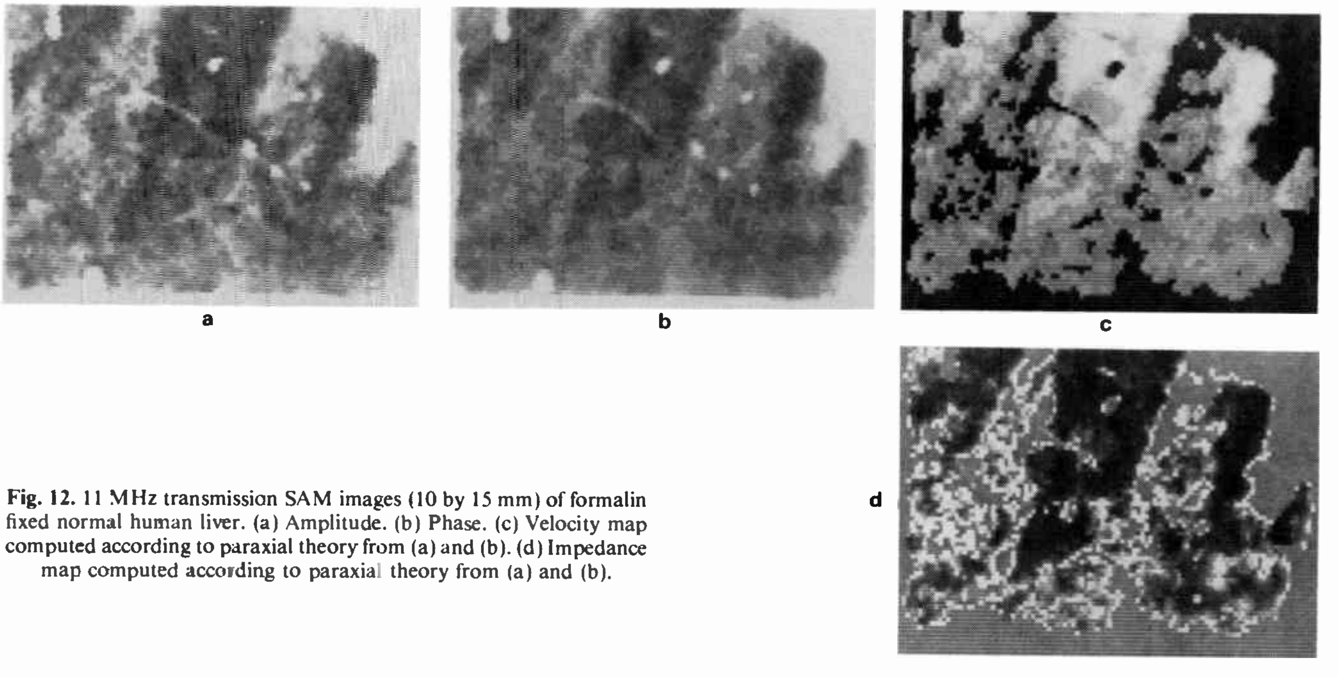


Fig. 12. 11 MHz transmission SAM images (10 by 15 mm) of formalin fixed normal human liver. (a) Amplitude. (b) Phase. (c) Velocity map computed according to paraxial theory from (a) and (b). (d) Impedance map computed according to paraxial theory from (a) and (b).

our experimental technique improves. We will now examine a more general method for elastic constants determination which is valid for an unrestricted range of material parameters.

7.2 Angular Probing Techniques for Elastic Constant Determination

The paraxial theory above relies on a single complex measurement when deducing the object properties at each point on the specimen. Often more than two independent constants are required to characterize the sample, e.g. longitudinal and shear velocities, surface wave velocity, density, viscosity and anisotropy. Thus the investigation of more general objects requires additional measurements at each point.

A suggested method for doing this[8] varies the object to lens spacing, z, at each object scan coordinate, and records the resultant microscope output, $V(z)$. The curve obtained, which has been called an 'acoustic materials signature',[19] is strongly characteristic of the object's surface wave velocity. In certain cases the longitudinal wave velocity and density of the sample may be directly measured from the $V(z)$ periodicity. The main disadvantage of the $V(z)$ method is that the equations which describe it cannot be simply inverted to determine the specimen properties. Furthermore, solution of the equations requires precise characterization of the microscope. We will now discuss two methods of elastic constant measurement that overcome these difficulties and suggest the possibility of measuring anisotropic elastic properties with high spatial resolution.

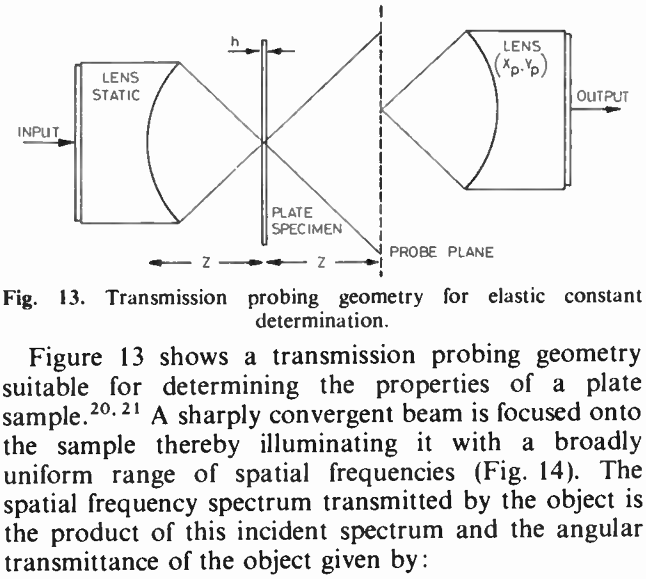


Fig. 13. Transmission probing geometry for elastic constant determination.

Figure 13 shows a transmission probing geometry suitable for determining the properties of a plate sample.[20, 21] A sharply convergent beam is focused onto the sample thereby illuminating it with a broadly uniform range of spatial frequencies (Fig. 14). The spatial frequency spectrum transmitted by the object is the product of this incident spectrum and the angular transmittance of the object given by:

$$U_3(f_x, f_y) = p(\lambda f_x R, \lambda f_y R) \,.\, T(f_x, f_y) \qquad (3)$$

where $P(x, y)$ is the pupil function of the illuminating source, R is the radius of curvature of the lens and $T(f_x, f_y)$ is the object transmittance[22] as a function of spatial frequency f_x, f_y. The distribution in space in the probing plane is found by using the Fresnel–Huygens diffraction formula:

$$u_4(x, y) = \exp(jk(x^2+y^2)/2S) \times \times p(xR/S, yR/S).\ T(X/\lambda S, y/\lambda S) \qquad (4)$$

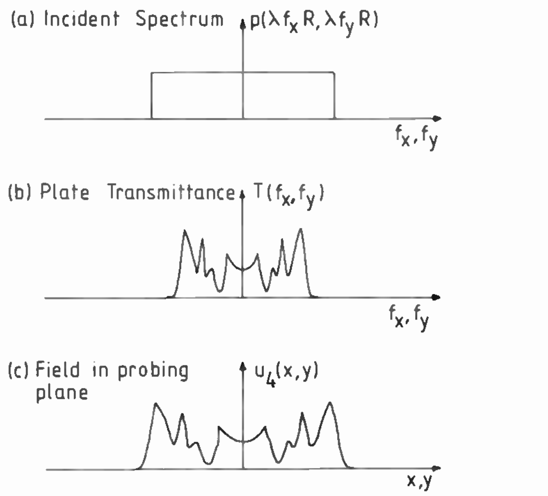


Fig. 14. Incident and transmitted fields and spectra in the transmission probing geometry of Fig. 13.

where S is the distance between the object and probing plane. The probe output is the convolution of this distribution with the spatial response of the probe. We have used a high resolution acoustic probe[23] in the experiments described here and the response of this may be closely approximated by a delta function. The probe output when the object is absent can be deduced from equation (4) with $T(f_x, f_y) = 1$. The ratio of the probe output with the object present to that obtained when it is absent is given by:

$$v_0(x, y) = \frac{u_4(x, y)_{\text{with specimen}}}{u_4(x, y)_{\text{without specimen}}} = T(x/\lambda S, y/\lambda S) \qquad (5)$$

The pupil function and propagation factors of the system have thus been calibrated out. Equation (5) gives the transmittance spectrum of the object in the region determined by the beamwidth at the object plane—typically of the order of a wavelength. Features in this spectrum are closely related to the longitudinal and shear wave critical angles at the interface between the object and the coupling fluid. A simple algorithm may be applied to determine these object velocities using Snell's law. The density of the object may be deduced from the value of $T(0, 0)$, once the longitudinal velocity is known.

Mechanical scanning is used to move the object through the incident beam and an image of the elastic constants can be built up by examining the probe plane distribution at each object point in sequence. Selection of the coupling fluid provides a means of placing the critical angles at convenient positions in the probing plane. The critical angle features can also be enhanced by choosing a liquid that is a good impedance match to the object. For example, mercury is suitable for high impedance materials and methanol or Flutec (C_7F_{14}) for plastics and soft tissues.[20]

Figure 15 shows the dimensions of an experiment to record the transmittance spectrum of a 1·65 mm thick duraluminium plate at 4 MHz. The field distribution recorded in the probing plane without the aluminium plate in position is shown in Fig. 16. This represents a mapping of the lens pupil function given by equation (4) with $T(f_x, f_y) = 1$. The amplitude scan shows the

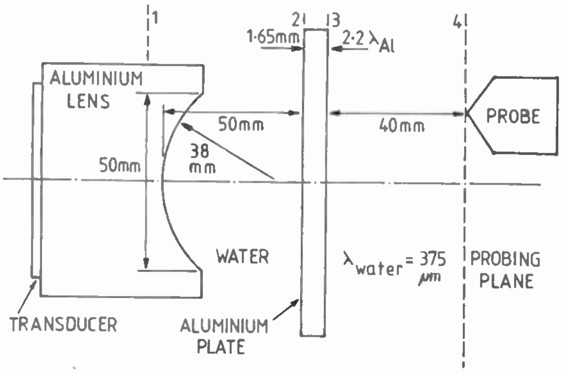
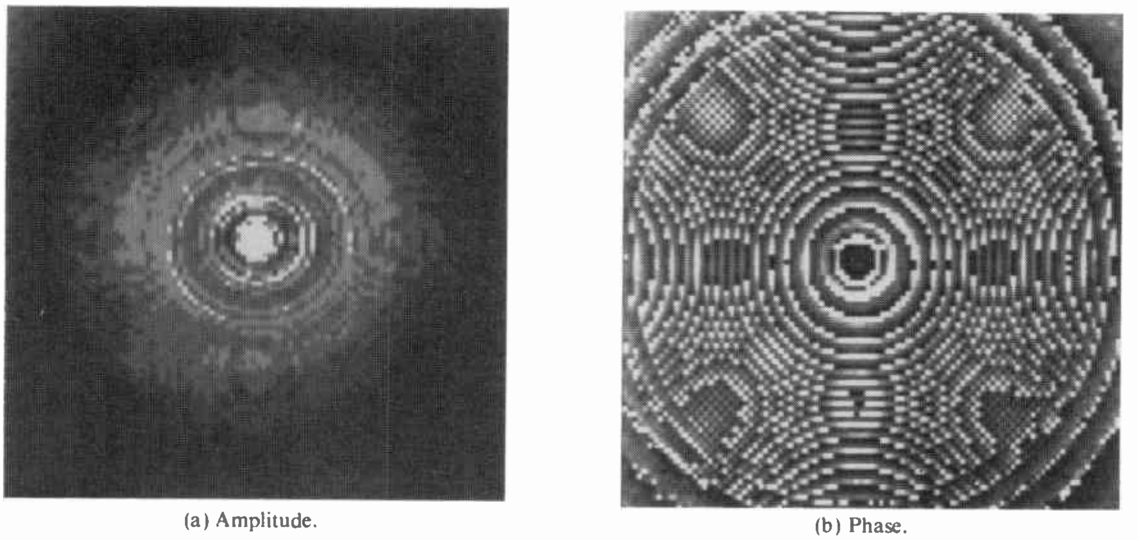


Fig. 15. Arrangement employed to measure the elastic constants of a 1·65 mm thick aluminium plate at 4 MHz.

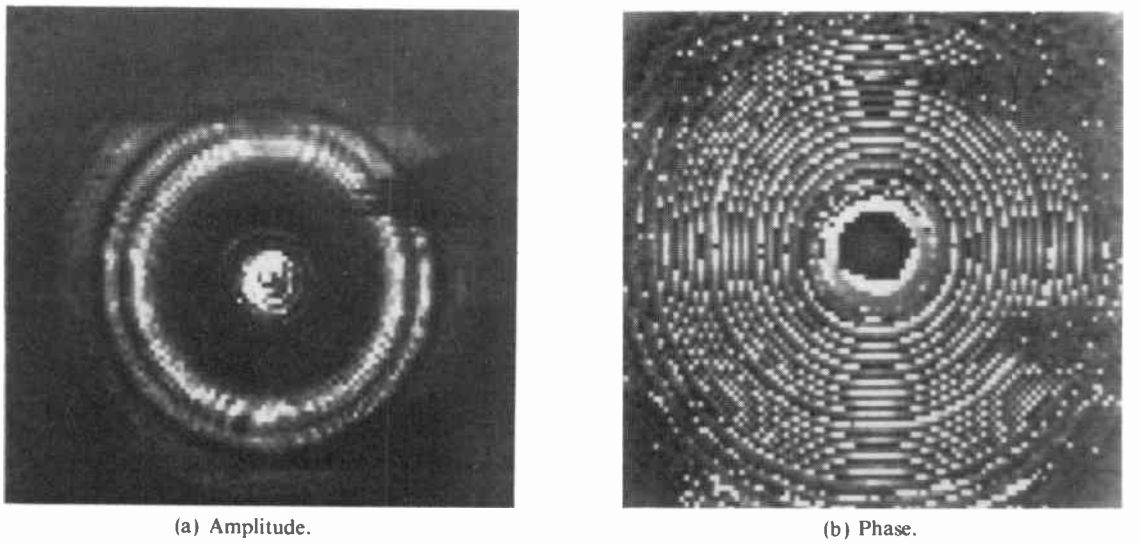
somewhat apodized lens response due to mode conversion at the lens-liquid interface. The phase image clearly demonstrates the expected curvature due to the exponential term in equation (4). The distribution recorded with the aluminium plate in position is shown in Fig. 17. The transmittance spectrum (obtained from equation (5), dividing image 17 by image 16) is shown in Fig. 18(a). A theoretical plot of the transmittance spectrum is shown for comparison in Fig. 18(b). This is in good agreement with the measured spectrum. In particular we note the two bright rings, characteristic of shear plate modes.

The isotropy of the sample is confirmed by the circular symmetry of the field distribution in the probing plane. The outer bright ring in the image can be used to determine the shear critical angle and the null ring near the centre of the scan is associated with the longitudinal critical angle. From a knowledge of the position of these features in the scan plane we compute the longitudinal and shear velocities to be 6200 and 3400 m/s. The textbook values are 6374 and 3140 m/s giving agreements of 3 and 9%. Hardening of the material during manufacture may account for some of this



(a) Amplitude. (b) Phase.

Fig. 16. Field distribution recorded in the probing plane of Fig. 15 in the absence of an object.



(a) Amplitude. (b) Phase.

Fig. 17. Field distribution recorded in the probing plane of Fig. 15 with the aluminium plate placed in the object plane.

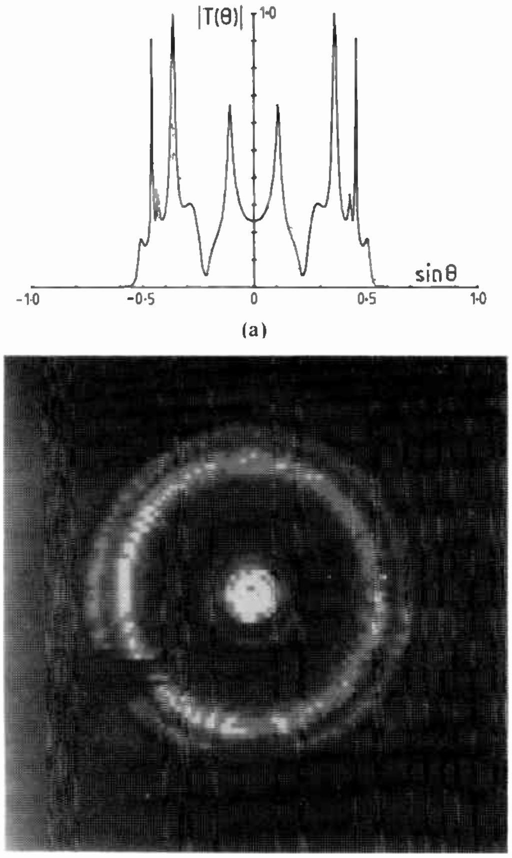


Fig. 18. (a) Theoretical plot of the transmittance spectrum of a 1·65 mm thick aluminium plate at 4 MHz. (b) Measured transmittance plot of aluminium plate computed from equation (5).

discrepancy.

We believe it would be feasible to implement this technique at high frequencies. Conventional SAM lenses would be used both to provide the broad spatial bandwidth illumination and to probe the field transmitted by the object. We have tested the recording geometry with 2 μm wavelength, and find that the signal levels are quite acceptable—it now remains to implement this elastic constants measurement with microscopic resolution.

Whilst the transmission probing geometry above provides a simple and accurate method for obtaining the elastic constants of a plate sample, it still retains some inconvenient practical features. The system must be pulsed to discriminate against reverberation. but, since the receive pulse transit time through the system is a spherical function of scan position, this can lead to the pulse falling outside the constant receiver time interval at extreme scan positions. The method also requires a calibration division (equation (5)) to remove the apodization association with the source pupil function and this can introduce high-frequency noise as well as necessitating digital signal processing facilities. Furthermore, the theory only applies in the Fresnel approximation and this is only strictly true for the paraxial rays in the transmitted beam.

These difficulties are overcome by the arrangement of Fig. 19.[21] A longitudinal plane wave uniformly illuminates the sample, the energy scattered from the region of the object at the focus of the lens is detected and produces the output signal. The entire lens and plane wave source assembly may be rotated about the focus at each scan coordinate. Mechanical scanning of the specimen is used to build up a picture in the usual fashion so that with the object normal to the incident beam the system acts as a conventional single lens SAM. Assuming that the specimen is uniform within the narrow focal region illuminated (a condition which can be ascertained from a dark field measurement) the effective lens response of the system is:

$$U_2(f_x, f_y) = \mathscr{F}[p_1(x, y)]|_{\substack{x=\lambda f_x F \\ y=\lambda f_y F}} \cdot p_s(x/A, y/A) \qquad (6)$$

where $p_1(x, y)$ is the pupil function of the lens, focal length F and aperture D, and $p_s(x, y)$ is the pupil function of the plane wave source of diameter A. $\mathscr{F}[\,]$ indicates the Fourier transform operation. The output of the system at object rotation angles $\theta_x = \sin^{-1}(\lambda f_{\theta x})$ and $\theta_y = \sin^{-1}(\lambda f_{\theta y})$ relative to the x and y axes is:

$$V_0(\theta_x, \theta_y) = \iint T(f_x - f_{\theta x}, f_y - f_{\theta y}) \times \times U_2(f_x, f_y) \, \mathrm{d}f_x \, \mathrm{d}f_y. \qquad (7)$$

If $A \gg \lambda$ (i.e. the source produces a very narrow range of spatial frequencies) then $U_2(f_x, f_y)$ approximates to a delta function and equation (7) reduces to the simple result:

$$V_0(\theta_x, \theta_y) = T(f_{\theta x}, f_{\theta y}) \qquad (8)$$

where $T(f_x, f_y)$ is again the angular transmittance of the object. Thus, rotation of the object permits the transmission spectrum of each pixel region in the object to be determined. Anisotropy of the sample will appear as an asymmetry in the transmission spectrum. The critical angles and normal reflectivity can be deduced from this curve and the elastic constants of the sample thereby deduced. There is no time-gate delay variation required in this system nor is the theory limited to a paraxial description.

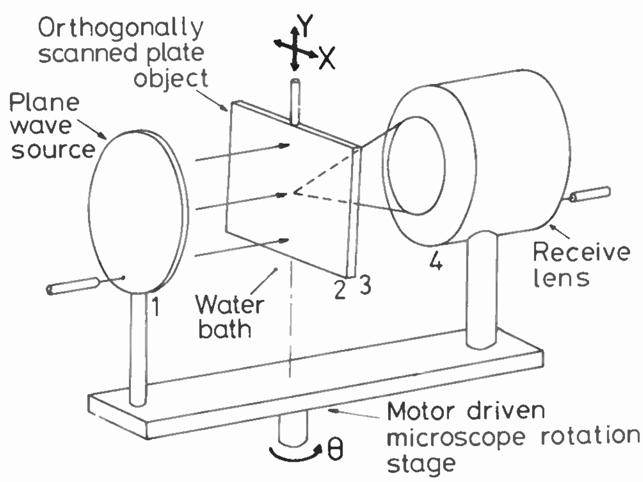


Fig. 19. Single lens acoustic microscope with added rotational degree of freedom.

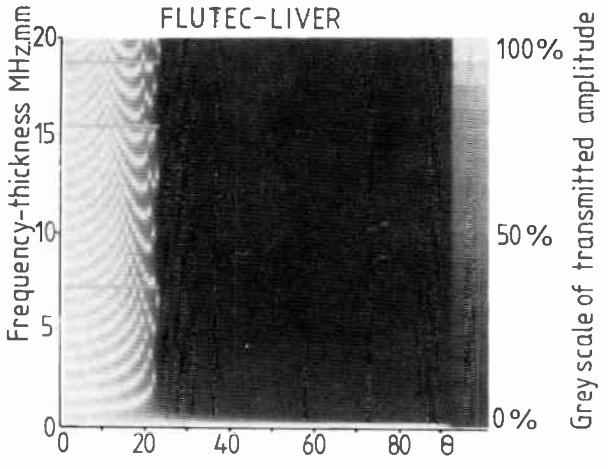


Fig. 20. Angular transmittance of an idealized liver section (velocity 1560 m/s, density 1060 kg/m^3) plotted on a grey scale as a function of plate thickness and frequency.

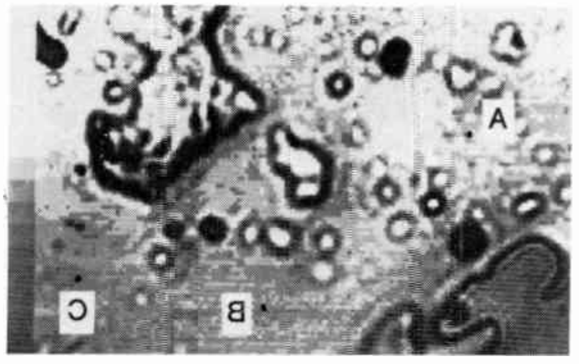


Fig. 21. Conventional single lens intensity image of a 450 µm thick section of formalin-fixed normal human liver—the field of view is 10 by 6 mm.

One important application for this technique is in the field of tissue characterization and B scan analysis where there is a need for fine scale data on the acoustic properties of tissue. In our preliminary experiments we have imaged a 450 µm thick, formalin fixed, normal human liver sample in a Flutec PP2 bath (C_7F_{14}, velocity 593 m/s, density 1788 kg/m^3) at 9·1 MHz. The angular transmittance of an idealized liver section (velocity 1560 m/s, density 1060 kg/m^3) as a function of its frequency-thickness product is shown in Fig. 20. There is a sharp cut-off at the longitudinal critical angle which is independent of thickness above 1·2 mm-MHz. This feature can be readily used to identify the longitudinal velocity, without an accurate measurement of the specimen thickness.

Table 1

Longitudinal velocity in normal liver computed from the rotational scans of Fig. 22

Scan	Critical angle (deg)	Computed velocity (m/s)
A	20·7	1680
B	20·3	1709
C	20·4	1700

The conventional single lens SAM intensity image of the sample is shown in Fig. 21. Rotational scans at the pixel locations indicated are shown in Fig. 22. Table 1 summarizes the velocities deduced from the scans of Fig. 22 and it can be seen there is generally good agreement between these and the expected values.[18]

A full theory of the probing experiments predicts a measurement accuracy of a few percent.[24] This accuracy can be substantially improved upon by curve fitting over the entire transmittance spectrum, thus optimizing the values of density, elastic moduli and thickness.

For an accurate spectral recording we require that the specimen is uniform within the illuminated region—diffraction at the specimen will confuse the measurement. We can consider the spatial resolution of the probing technique as being the distance away from a diffracting boundary that the focal spot must be in order to obtain a specified accuracy of measurement. This relates to the acoustic beamwidth inside the specimen. In order to demonstrate this we have recorded the rotational spectra of a sheet of aluminium in water (9·1 MHz, 0·65 mm thickness) along a line scan which crosses the edge of the sheet (Fig. 23). The rotational angle is on the horizontal axis and the scan position is on the vertical axis, with the edge of the aluminium halfway up the image. The upper half, being water, has a correspondingly high and uniform spectral transmittance. The rotational information is unaffected up to about two wavelengths from the edge of the sheet, indicating the likely resolution in metallic specimens.

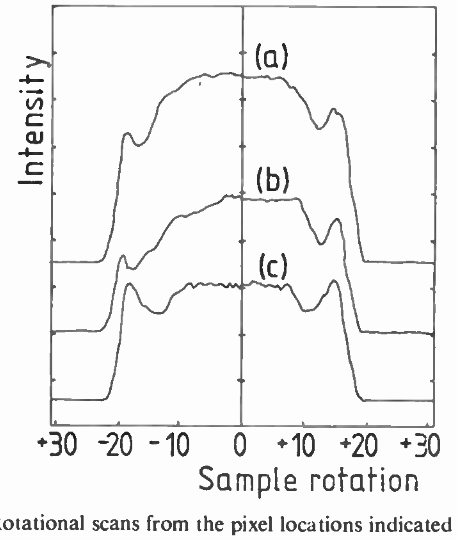


Fig. 22. Rotational scans from the pixel locations indicated in Fig. 20.

8 Interior Imaging

There are many applications in the field of non-destructive testing that involve the examination of the interior of opaque, solid materials, e.g. crack detection in welds, delaminations in integrated circuits. It might, at first, be thought that SAM examination of such metallic objects could be difficult due to the aberrations and high signal loss associated with the large velocity and impedance mismatch at the object surface. There are two possible techniques for getting round these difficulties. The first replaces the water lens-object couplant with a

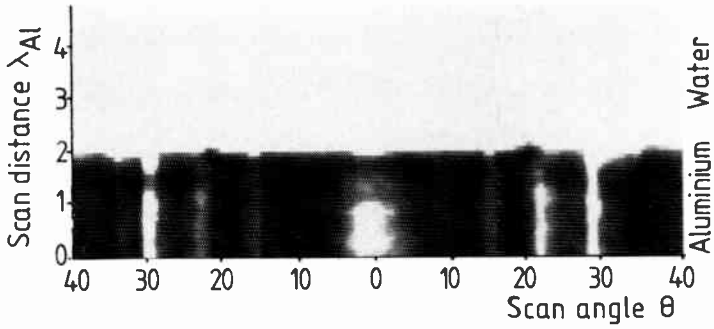


Fig. 23. Intensity of rotational spectra plotted on a grey scale as a function of incidence angle and scan distance from an aluminium/water edge measured with the arrangement of Fig. 19 at 9·1 MHz.

liquid metal.[25] This provides a good impedance match into shear waves in a metallic object, and diffraction limited imaging then becomes possible using the mode converted shear wave beam. Because shear wavelengths are invariably smaller than longitudinal wavelengths a resolution advantage is also obtained. Practical problems can be encountered either in achieving adequate wetting of the object surface or if the sample is soluble in the liquid metal.

Alternatively, diffraction-limited performance can be achieved with a simple spherical lens of restricted aperture ($f4$–$f10$).[26,27] The optimum lens aperture is determined primarily by the object velocity. This is because the focal plane properties of a given aperture lens are relatively insensitive to the depth of the image plane within the object. Figure 24 shows the focal plane distribution of a reduced aperture $f4$ lens focused inside an aluminium block; refraction produces a 30° half-angle beam within the aluminium. The 3 dB beamwidths are within 10% of the diffraction limit imposed by the lens aperture. As a demonstration of the interior imaging properties of the SAM, Fig. 25 shows an image of a resolution test object consisting of buried slots in a brass block. These wavelength-wide features are clearly resolved.

Figure 26 shows a transmission SAM image of a PZT5 piezoelectric ceramic disk longitudinal mode transducer (320 μm thick with aluminized open circuit electrodes) imaged at 50 MHz.[28] The wavelength in the transducer material was 87 μm. While some of the contrast in this image is directly attributable to variations in electrode thickness and adhesion, much of the fine structure in the image is also due to density and velocity variations within the transducer material. It is clear from the acoustic image that this transducer will not act as a simple idealized piston radiator. Assessment of the efficiency of localized areas of transducers should lead to improved transducer fabrication techniques.

An additional mode of operation is possible when piezoelectric objects are examined in the SAM. In this 'self-detection' mode, shown in Fig. 27, the transducer disk under examination is itself used to detect the signal generated by the focused sound beam. The image depends on both the mechanical and piezoelectric properties of the sample. Figure 28 shows an image

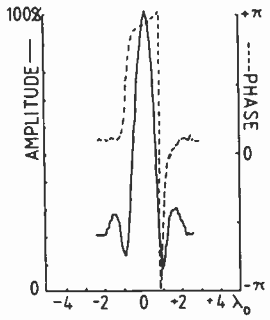


Fig. 24. Focal plane distribution of an $f4$ lens focused at a depth of 10 λ below the surface of an aluminium block.

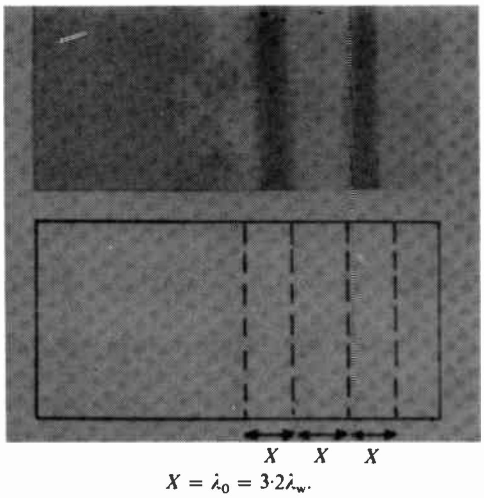


Fig 25. Image of buried slots, 2λ below the surface of a brass block. The subscripts o and w refer to the object and water respectively.

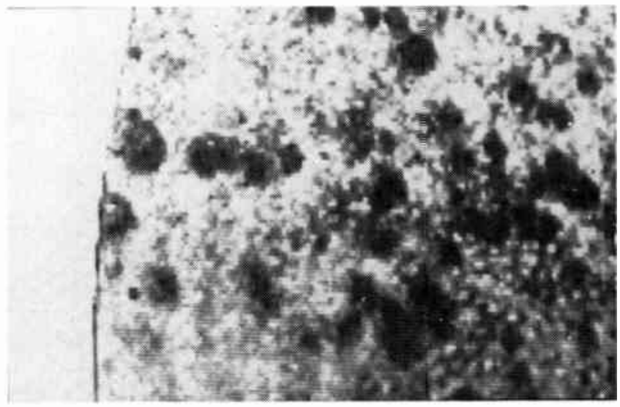


Fig. 26. Transmission scanning acoustic microscope image of a 320 μm thick PZT5 transducer imaged at 50 MHz—the field of view is 3 by 2 mm.

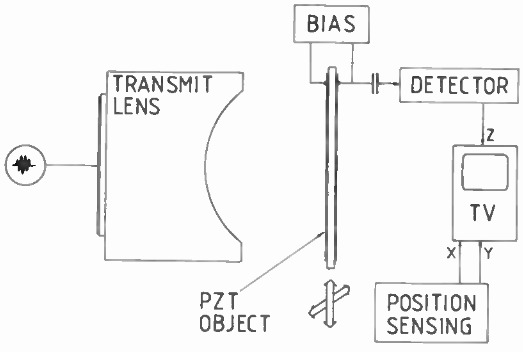


Fig. 27. Arrangement for SAM self-detection imaging of piezoelectric transducers.

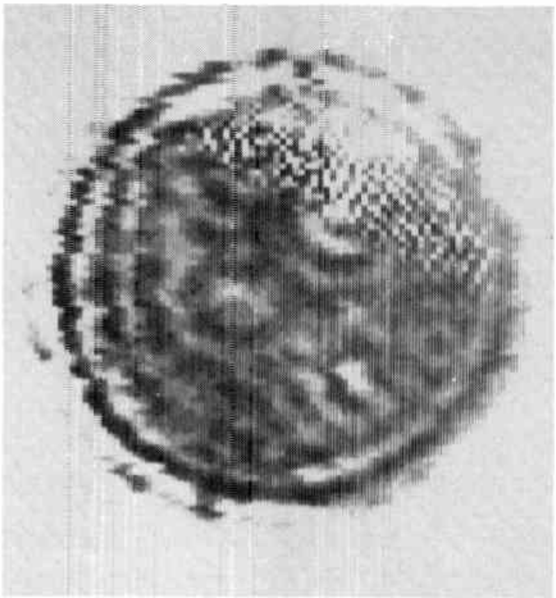


Fig. 28. 3·4 MHz acoustic microscope image of a PZT5A transducer taken using the self-detection mode of Fig. 27.

taken in this mode of a longitudinal wave PZT5A transducer operating at a frequency of 3·4 MHz where the wavelength in the transducer was 690 μm. There is approximately 5 dB variation in this image and so the transducer performance seems to be quite non-uniform. These initial measurements were quite surprising to us since they show significant spatial variations in the properties of transducers. It is well known that there are many second-order variations in transducer performance that are difficult to measure and analyse. The acoustic microscope can assist in the investigation of these effects.

In another application of interior imaging we have examined a composite object formed by sintering a diamond-carbon mixture onto a 10 mm diameter steel base.[29] The thicknesses of the carbon-diamond and steel layers were 1·3 and 6·1 diamond and steel wavelengths respectively. The purpose of this study was to see whether non-uniformities in the sintered material or delaminations at the carbon-diamond/steel interface could be detected in this opaque object. Figure 29(a) shows an 11 MHz transmission SAM intensity image of a 'good' sample in which there is relatively little acoustic contrast in the sample. Indeed over about two-thirds of the sample the transmissivity varies by less than 2 dB. Figure 29(b) on the other hand shows a 'bad' sample in which there is low overall transmission and no discernible areas of uniformity. This sample is clearly defective.

So far we have talked about improved methods for the detection and interpretation of acoustic micrographs. This work will finally come to fruition in the high resolution instruments which are being developed and so we will now consider the present frontiers in high resolution microscopy.

9 Gas-medium Acoustic Microscopy

By stretching the existing technology to its limits, the reflection SAM has been operated in water at 3·5 GHz, with a corresponding wavelength of 425 nm.[8] The major obstacle to improving the resolution of the SAM is the high value of the absorption of sound in liquids—generally this increases with the square of frequency. To

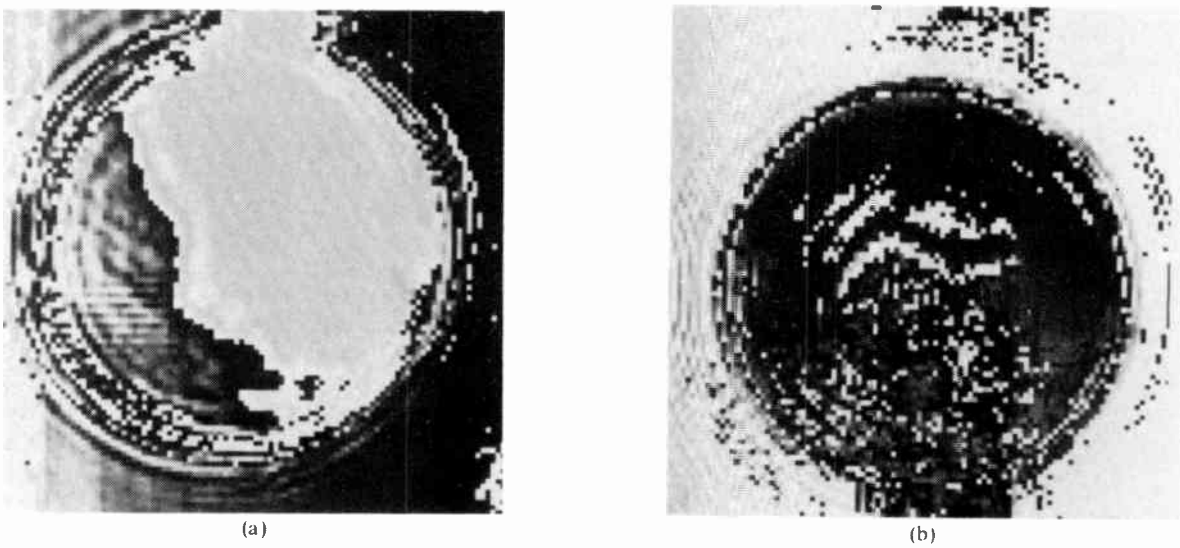


Fig. 29. 11 MHz transmission SAM intensity images of a carbon-diamond material sintered to a steel base—the field of view is 12 × 12 mm. (a) 'Good' sample showing reasonable uniformity of transmission. (b) 'Poor' sample showing low, non-uniform transmission.

obtain a wavelength below 425 nm one must find a fluid which has a lower velocity, a lower absorption coefficient, or preferably both. One possibility is to use cryogenic liquids such as argon and helium.[30] However, the use of such liquids involves several instrumental complexities as well as restricting the type of sample which can be investigated. We have begun to explore an alternative class of fluid—gases at high pressure.

It is well known that the velocity of sound in gases is 5–10 times lower than in most liquids, although the acoustic absorption is typically 100–1000 times higher. We have shown that the acoustic absorption—at least in the case of monatomic gases such as argon and xenon—varies inversely with pressure. Therefore it should, in principle, be possible to exceed the resolution limit in water using gases at elevated pressures.[3] The results of our initial work in this area, where we demonstrated a reflection SAM operating in argon at 30 bar and 45 MHz have already been published.[32] The resolution was five times better than that which could be achieved in water at the same frequency.

We can define a coefficient of merit M for a coupling fluid in the SAM by calculating the minimum wavelength that can be achieved for a fixed loss and transit time within the fluid, and relating it to the corresponding value for water:

$$M = \left(\frac{\alpha_w}{\alpha}\right)^{\frac{1}{2}} \cdot \left(\frac{c_w}{c}\right)^{\frac{3}{2}} \qquad (9)$$

where c is the velocity of sound in the fluid, α is the attenuation coefficient normalized with respect to the square of frequency f, and the subscript w refers to corresponding quantities in water. Table 2 lists the coefficient of merit for several liquids and gases. It is clear that gases such as argon and xenon under pressure can provide substantial improvements in resolution over water. Specifically, argon at 40 bar will provide a factor of two improvement, while xenon will improve resolution by a factor of 4. The figure of merit rises with the square root of pressure so that at 250 bar the value in argon is 5.

We are currently working on a system which will use argon at 40 bar as the coupling fluid and a 10 μm radius lens as the imaging element. We expect to obtain a resolution of 220 nm at 1 GHz. Finally, we are in the process of constructing an instrument that would operate at much higher pressures (around 250 bar) with the aim of attaining resolutions well below 100 nm.

Table 2

Coefficient of merit for various fluids

Fluid	Temperature	Longitudinal velocity (m/s)	Absorption (s^2/cm)	M
Water	25°C	1495	22·0	1·0
Water	37°C	1523	17·7	1·0
Water	60°C	1550	10·2	1·4
Carbon disulphide	25°C	1310	10·1	1·8
Mercury	23·8°C	1450	5·8	2·0
Argon	85 K	853	10·1	3·2
Helium	1·95 K	227	61·0	9·5
Argon (40 bar)	20°C	323	412·0	2·0
Argon (250 bar)	20°C	323	83·0	5·0
Xenon (40 bar)	20°C	178	953·0	4·0

10 Conclusion

For the sake of brevity, we have restricted our review to cover only developments initiated within this Department. Acoustic microscopy currently attracts worldwide interest and the progress made in nine years has been meteoric. It would be surprising indeed if after this short period the acoustic microscope posed a direct threat to the optical instrument. In its three hundred years of development it is not just the instrumental refinements which make the optical technique powerful, but the vast wealth of operating experience and documentation of results. Thus the optical microscope will for long be the basis of comparison. Such hard-won knowledge is not given up lightly!

We feel that the SAM is complementary to optical methods and offers some unique possibilities. Because acoustic contrast seems to be inherent in biological materials, the SAM obtains images without staining. This can reduce the number of artefacts as well as the specimen preparation time. Thus, new structures may be viewed in finer detail than before. Identification of materials will rely upon their shape, as well as their elastic properties, and we are particularly keen on developing the elasticity measurement techniques; in these lie the acoustic basis of comparison. The sensitivity of the instrument is gradually being improved. Often this is just a case of redesigning the electronics, but new geometries such as dark field and differential phase contrast are extending the frontiers of the detectable.

Non-destructive testing applications are being developed—imaging the interior of opaque objects is as attractive for testing integrated circuits as for measuring the strength and adhesion of structural materials. The differential imaging technique will show how these properties vary with time. Finally, we are developing the gas microscope to obtain even higher resolution at room temperature. Just how far these developments will be successful will be clearer in ten years time . . . in another two hundred and ninety maybe things will look different!

11 Acknowledgments

Our work has been inspired by Eric A. Ash, and we have benefited immeasurably from his advice and encouragement.

It is a pleasure to acknowledge the support of the Science and Engineering Research Council, the Medical Research Council, British Telecom and the National Research Development Corporation.

We are most grateful to C. F. Quate who has encouraged the research programme at University College since its inception. Additional thanks are due to C. R. Hill and D. Nicholas at the Institute of Cancer Research, Royal Marsden Hospital, Surrey, and D. Rothwell and I. D. J. Burdett at the National Institute for Medical Research, Mill Hill, for advice and assistance with the medical and biological aspects of the work.

Finally, we wish to acknowledge the many helpful and useful contributions made to this work by all our past and present colleagues at University College London.

12 References

1 Lemons, R. A. and Quate, C. F., 'Acoustic microscopy by mechanical scanning', *Appl. Phys. Letters*, **24**, pp. 163–4, 1974.
2 Sokolov, S., 'An ultrasonic microscope', *Dokl. Akad. Nauk*, **64**, pp. 333–5, 1949.
3 Kessler, L. E. and Yuhas, D. E., 'Acoustic microscopy—1979', *Proc. IEEE*, **67**, pp. 526–35, April 1979.
4 Cunningham, J. A. and Quate, C. F., 'High resolution acoustic imaging by contact printing', in 'Acoustic Holography', vol. 5, ed. P. S. Green, p. 83 (Plenum Press, New York, 1972).
5 Auld, B., Gilbert, R. J., Hyllested, K. and Roberts, C. G., 'A 1·1 GHz scanned acoustic microscope', in 'Acoustic Holography', vol. 4, ed. G. Wade, p. 73 (Plenum Press, New York, 1972).
6 Quate, C. F., Atalar, A. and Wickramasinghe, H. K., 'Acoustic microscopy with mechanical scanning—a review', *Proc. IEEE*, **67**, pp. 1092–1114, August 1979.
7 Gill, D. K., Kirchener, E. K. and Khuri-Yakub, B. T., 'Zinc oxide transducer for microwave bulk-wave devices', IEEE Ultrasonics Symposium, Boston, USA, November 1980, pp. 805–7 (IEEE cat. no. 80CH1602–2).
8 Quate, C. F., 'Microwaves, acoustics and scanning microscopy', in 'Scanned Image Microscopy', ed. E. A. Ash, pp. 23–56 (Academic Press, London, 1980).
9 Born, M. and Wolf, E., 'Principles of Optics', p. 423 (Pergamon Press, Oxford, 1959).
10 Atalar, A., Quate, C. F., and Wickramasinghe, H. K., 'Phase imaging in reflection with the acoustic microscope', *Appl. Phys. Letters*, **31**, pp. 791–3, 1977.
11 Bennett, S. D. and Ash, E. A., 'Differential imaging with the acoustic microscope', *IEEE Trans on Sonics and Ultrasonics*, SU-**28**, no. 2, pp. 59–64, March 1981.
12 Leung, W., Shaw, H. J., Kino, G. S., Winslow, D. K. and Zitelli, L. T., 'Acoustic phase contrast with electronic scanning', IEEE Ultrasonics Symposium, 1976 (IEEE cat. no. 76CH1120–5SU).
13 Smith, I. R. and Wickramasinghe, H. K., 'Differential phase contrast in the acoustic microscope', *Electronics Letters*, **18**, no. 2, pp. 92–4, January 1982.
14 Bond, W. L., Cutler, C. C., Lemons, R. A. and Quate, C. F., 'Dark field and stereo viewing with the acoustic microscope', *Appl. Phys. Letters*, **31**, no. 12, p. 791, 1977.
15 Sinclair, D. A. and Smith, I. R., 'Dark field acoustic microscopy', *Electronics Letters*, **16**, no. 16, pp. 627–9, 1980.
16 Smith, I. R. and Sinclair, D. A., 'Dark field acoustic microscope', Conference Proceedings, 10th International Symposium on Acoustic Imaging, Cannes, France, October 1980.
17 Bennett, S. D., 'Approximate materials characterisation by coherent acoustic microscopy', *IEEE Trans on Sonics and Ultrasonics*. To be published.
18 Goss, S. A., Johnston, R. L. and Dunn, F., 'Comprehensive compilation of empirical ultrasonic properties of mammalian tissues', *J. Acoust. Soc. Am.*, **64**, no. 2, pp. 423–57, 1978.
19 Weglein, R. D. and Wilson, R. G., 'Characteristic material signatures by acoustic microscopy', *Electronics Letters*, **14**, p. 352, 1978.
20 Smith, I. R., Sinclair, D. A. and Wickramasinghe, H. K., 'Acoustic microscopy of elastic constants', IEEE Symposium on Ultrasonics, Boston, USA, October 1980.
21 Smith, I. R., Sinclair, D. A. and Wickramasinghe, H. K., 'Acoustic microscopy of slowness surfaces', IEEE Symposium on Ultrasonics, Chicago, USA, October 1981.
22 Brekhovksikh, L. M., 'Waves in Layered Media', p. 44, 2nd ed. (Academic Press, London, 1980).
23 Duerr, W., Sinclair, D. A. and Ash, E. A., 'A high resolution acoustic probe', *Electronics Letters*, **16**, no. 21, pp. 805–06, 9th October 1980.
24 Wickramasinghe, H. K., Smith, I. R. and Sinclair, D. A., 'Quantitative material characterisation using acoustic microscopy', IEEE Ultrasonics Symposium, San Diego, USA, November 1982.
25 Jipson, V. B., 'Acoustic microscopy of interior planes', *Appl. Phys. Letters*, **35**, pp. 385–7, 1979.
26 Tsai, C. S., Wang, S. K. and Lee, C. C., 'Visualisation of solid material joints using a transmission type scanning acoustic microscope', *Appl. Phys. Letters*, **31**, no. 5, p. 317, 1977.
27 Pino, F., Sinclair, D. A. and Ash, E. A., 'New technique for subsurface imaging using scanning acoustic microscopy', Ultrasonics International 1981, Brighton, England, 30th June to 2nd July 1981 (IPC Science and Technology Press, Guildford, 1981).
28 Bond, L. J., Jayasundere, N., Sinclair, D. A. and Smith, I. R., 'Investigation of ultrasonic transducers as used for non-destructive testing', DARPA Review of Progress in Quantitative NDA, Boulder, Colorado, August 1981.
29 Sinclair, D. A. and Ash, E. A., 'Bond integrity evaluation using transmission scanning acoustic microscopy', *Electronics Letters*, **16**, no. 23, pp. 880–2, 1980.
30 Heiserman, J., Rugar, D. and Quate, C. F., 'Cryogenic acoustic microscopy', *J. Acoust. Soc. Am.*, **67**, pp. 1629–37, 1980.
31 Wickramasinghe, H. K. and Petts, C. R., 'Acoustic microscopy in high pressure gases', IEEE Symposium on Ultrasonics, Boston, USA, November 1980, pp. 668–72 (IEEE cat. no. 80CH1602–2).
32 Wickramasinghe, H. K. and Petts, C. R., 'Gas medium acoustic microscopy', in 'Scanned Image Microscopy', ed. E. A. Ash, pp. 57–70 (Academic Press, London, 1980).

Manuscript first received by the Institution on 27th January 1982 and in final form on 7th April 1982
(*Paper No. 2051/M129*)

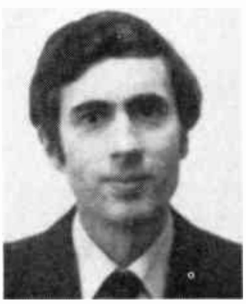
Contributors to this issue

H. V. SHURMER

D. A. SINCLAIR

John Ball joined British Telecom in 1953 and worked on telephone exchange and repeater maintenance until returning to full-time studies in 1962. He received B.Sc. and M.Sc. degrees from Aston University in 1966 and 1968 respectively. Since transferring to BTRL in 1967 he has worked on digital regenerators for terrestrial microwave radio sytems and was involved in the millimetric waveguide project. Mr Ball is currently head of the mobile radio systems group at Martlesham.

David Abbott studied at Southampton University where he gained the B.Sc. degree in Electronics in 1973. He then joined the Plessey Allen Clark Research Laboratory at Caswell, where he worked on f.e.t. design and applications. Under an industrial studentship from the Science Research Council he set up an automatic noise figure measurement facility at Warwick University. In 1979 he took charge of a microwave test facility at M.E.L., Crawley, where he is now developing new systems.



J. R. BALL

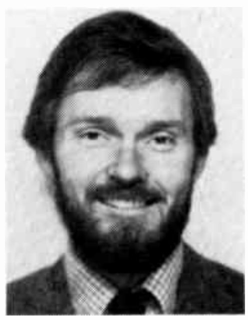
D. A. ABBOTT

Harold Shurmer received the M.Sc. degree from the University of Wales in 1948, followed by the degrees of Ph.D. and D.Sc. (Eng.) from London University. He worked on semiconducting devices at the former AEI Research Laboratory at Rugby until his move to Warwick University in 1969, where he has been Reader in Engineering Science since 1979 and he is currently Deputy Chairman of the School of Electronics. Dr. Shurmer has contributed numerous papers to the technical press including three in *The Radio and Electronic Engineer* and is author of a book 'Microwave Semiconductor Devices'.

David Sinclair graduated from Cambridge University in 1976 having read electrical science. He then carried out research on tissue and materials characterization using acoustic microscopy at University College London which led to the award of a Ph.D. in 1981. He is currently a research assistant at UCL, working on further applications of acoustic microscopy.

Ian Smith read electronic engineering at University College London, graduating in 1977. He then carried out research in scanning acoustic microscopy at UCL and obtained the Ph.D. degree in 1981. He is currently an Associate Research Assistant at UCL, exploring commercial implementations and applications for the acoustic microscope with the Wolfson Unit for Microscopic Non-Destructive Testing.

Kumar Wickramasinghe obtained his B.Sc. (Eng.) and Ph.D. degrees from the University of London in 1970 and 1974 respectively; his thesis work at University College was on high-frequency acoustic holography in solids. After a postdoctoral spell at University College, he joined the Edward L. Ginzton Laboratory at Stanford University where he worked on various aspects of research into acoustic and photoacoustic microscopy. He was appointed a Lecturer in the Department of Electrical Engineering at University College London in 1978 where he is currently continuing research into new forms of scanning microscopy.



I. R. SMITH

H. K. WICKRAMASINGHE

Conferences, Courses and Exhibitions, 1982-83

The date and page references in italics at the end of an item are to issues of *The Radio and Electronic Engineer (REE)* or *The Electronics Engineer (EE)* in which fuller notices have been published.
The symbol ★ indicates that the IERE has organized the event.
The symbol ● indicates that the IERE is a participating body.
An asterisk * indicates a new item or information which has been amended since the previous issue.

Further information should be obtained from the addresses given.

1982

OCTOBER

● RADAR '82 *18th to 20th October LONDON*
International Conference on Radar, organized by the IEE in association with the IEEE EUREL, IERE, IMA, RAeS and RIN, to be held at the Royal Borough of Kensington and Chelsea Town Hall, Hornton Street, London W8. Information: IEE Conference Department, Savoy Place, London WC2R 0BL. (Tel. 01-240 1871).

● Militery Microwaves '82 *19th to 22nd October LONDON*
Third International Conference and Exhibition organized by Microwave Exhibitions and Publishers, to be held at The Cunard International Hotel. Information: Military Microwaves '82 Conference, Temple House, 36 High Street, Sevenoaks, Kent TN13 1JG

Multivariable Systems *26th to 28th October PLYMOUTH*
Symposium on the Application of Multivariable Systems Theory, organized by the Institute of Measurement and Control to be held at the Royal Naval Engineering College, Manadon. Information: The Institute of Measurement and Control, 20 Peel Street, London W8 7PD. (Tel. 01-727 0083).

Instrumentation *26th to 28th October LONDON*
Electronic Test & Measuring Instrumentation Exhibition and Conference, to be held at the Wembley Conference Centre. Information: Trident International Exhibitions Ltd, 21 Plymouth Road, Tavistock, Devon PL19 8AU. (Tel. (0822) 4671).

Pattern Recognition *19th to 22nd October MUNICH*
Sixth International Conference on Pattern Recognition, sponsored by the IEEE in association with the IAPR and DAGM, to be held at the Technical University of Munich. Information: Harry Hayman, P.O. Box 369, Silver Spring, MD 20901 (Tel. (301) 589-3386).

Broadcasting *19th to 21st October SAARBRUCKEN*
Conference on Broadcasting Satellite Systems organized by the VDE(NTG) with the association of the specialized groups of the DGLR and the IRT. Information: Herrn Dipl. Ing. Walter Stosser, AEG-Telefunken, Gerberstrasse 33, 7150 Backnang

Manufacturing Technology *26th to 28th October GAITHERSBURG*
Fourth IFAC/IFIP Symposium on Information Control Problems in Manufacturing Technology organized by the National Bureau of Standards, US Department of Commerce, in association with IFAC/IFIP will be held in Gaithersburg, Maryland. Information: Mr J. L. Nevins, Vice Chairman, National Organizing Committee, 4th IFAC/IFIP Symposium Charles Stark Draper Labs, Inc. 555 Technology Square Cambridge, MA 02139 USA. (Tel. (617) 258 1347)

NOVEMBER

Robotics *2nd to 4th November LONDON*
International Conference on Robot Vision and Sensory Control—'Intelligent Robot Systems for the Mid Eighties'. Information: Conference Director, IFS (Conferences) Ltd 35-39 High Street, Kempston, Bedford

***Remote Sensing** *10th to 11th November LONDON*
A meeting on the Study of the Ocean and the Land Surface from Satellites organized by the Royal Society, will be held in London. Information: The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG (Tel. 01-839 5561)

Computers *16th to 19th November LONDON*
Compec Exhibition, to be held at the Olympia Exhibition Centre, London. Information: IPC Exhibitions Ltd, Surrey House, 1 Throwley Way, Sutton, Surrey SM1 4QQ. (Tel. 01-643 8040).

***ROBOTS** *22nd November LONDON*
Symposium on Robots: Applications and Opportunities for Industry organized by the IEEIE in association with the ITEME, will be held in London. Information: The Conference Secretary, IEEIE, 2 Savoy Hill, London WC2R 0BS. (Tel. 01-836 3357)

Safety *23rd to 25th November SEVENOAKS*
A three-day course on Safety of Electrical Instrumentation in Potentially Explosive Atmospheres, organized by SIRA Institute, will be held at Cudham Hall, Sevenoaks, Kent. Information: Conferences and Courses Unit, SIRA Institute Ltd, South Hill, Chislehurst, Kent BR7 5EH (Tel. 01-467 2636)

***SPEMAC** *26th November to 5th December GENEVA*
International Exhibition of Special Technics will be held in Geneva at the PALEXPO exhibition hall. Information: Joint Secretariat, 8 rue du 31-Decembre, CH-1007, Geneva.

DECEMBER

Electrical Safety *1st to 3rd December LONDON*
Conference on Electrical Safety in Hazardous Environments, organized by the IEE. Information: Conference Department, Institution of Electrical Engineers, Savoy Place, London WC2R 0BL. (Tel 01-240 1871)

***Micro-Imaging** *3rd December HEMEL HEMPSTEAD*
A one day Seminar sponsored jointly by Kodak and Micro-Image Technology, will be held at Hemel Hempstead. Information: Nicholas Mendes & Associates, Midland House, New Road, Halesowen, West Midlands. (Tel. 021-550 1827)

ONLINE *7th to 9th December LONDON*
The Sixth International Online Information Meeting, organized by *Online Review*, will be held at the Cunard Hotel, London. Information: Organizing Secretary, Online Information Meetings, *Online Review*, Learned Information, Besselsleigh Road, Abingdon, Oxford OX13 6LG. (Tel. 0865-730275)

INDEX-EL '82 *10th to 15th December ATHENS*
Second International Electrical & Electronics Engineering Exhibition, will be held at The Zappio Palace, Athens. British exhibits sponsored by EEA. Information: EEA, 8 Leicester Street, London WC2H 7BN. Tel. 01-437 0678.

Computers *14th December BIRMINGHAM*
A one-day Seminar on Using Personal Computers in Industry, organized by Sira Institute, will be held at the University of Aston in Birmingham. Information: Conference Unit, Sira Institute, South Hill, Chislehurst, Kent.

***TENCON '82** *6th to 8th December HONG KONG*
International Conference on the development and application of integrated circuits, organized by the Hong Kong Section of the IEEE, will be held in Hong Kong. Information: Hong Kong Trade Development Council, 14-16 Cockspur Street, London SW1Y 5DP. (Tel. 01-930 7955)

***Remote Sensing** *15th to 17th December LIVERPOOL*
Annual Conference on Remote Sensing and the Atmosphere to be held in Liverpool. Information: Dr A. Henderson-Sellers, Geography Department, University of Liverpool, P.O. Box 147, Liverpool L69 3BX

1983

JANUARY

***Visodata** *17th to 21st January MUNICH*
Fifth Visodata display and exhibition will be held at the Munich Trade Fair Grounds. Information: Visodata '83, Messegelande, Postfach 12 10 09, D-8000 Munchen 12. (Tel. (089) 51 07-1)

Computer Simulation *27th to 29th January SAN DIEGO*
Multiconference on Modelling and Simulation on Microcomputers organized by The Society for Computer Simulation, will be held at the Holiday Inn, Embarcadero, San Diego. Information: SCS, P.O. Box 2228, La Jolla, California 92038, U.S.A.

FEBRUARY

MECOM '83 *7th to 10th February BAHRAIN*
Third Middle East Electronic Communications Show and Conference, organized by Arabian Exhibition Management, to be held at the Bahrain Exhibition Centre. Information: Dennis Casson, MECOM '83, 49/50 Calthorpe Road, Edgbaston, Birmingham B15 1TH. (Tel. (021) 454 4416).

MARCH

Component Assembly *March BRIGHTON*
Brighton Electronics Exhibition on matching components with insertion, connection and assembly aids and techniques, to be held in Brighton. Information: The Press Officer, Trident International Exhibitions Ltd, 21 Plymouth Road, Tavistock, Devon PL19 8AU. (Tel. (0822) 4671).

***Audio-Video** *6th to 10th March ABU DHABI*
First comprehensive international exhibition for consumer electronics in the Gulf Area organized by AMK Berlin in association with the Gulf Arab Marketing and Exhibition Company, will be held in Abu Dhabi. Information: AMK Berlin. Postfach 191740, Messedamm 22, D-1000 Berlin 19. (Tel. (030) 30 38-1)

***Radio Communicetions** *21st to 25th March BRIGHTON*
Second International Network Planning Symposium, organized by the IEE, will be held in Brighton. Information: Conference Department, IEE, Savoy Place, London WC2R 0BL (Tel. 01-240 1871)

● Telecommunications Networks *21st to 25th March BRIGHTON*
Second International Network Planning Symposium (Networks '83), organized by the Institution of Electrical Engineers with the association of the IERE, to be held at the University of Sussex, Brighton. Information: IEE Conference Department, Savoy Place, London WC2R 0BL. (Tel. 01-240 1871).

Inspex '83 *21st to 25th March BIRMINGHAM*
Tenth International Measurement and Inspection Technology Exhibition, sponsored by *Measurement and Inspection Technology* in association with IQA and Gauge and Tool Makers' Association, to be held at the National Exhibition Centre, Birmingham. Information: Exhibition Manager, Inspex '83, IPC Exhibitions Ltd, Surrey House, 1 Throwley Way, Sutton, Surrey SM1 4QQ. (Tel. 01-643 8040).

APRIL

Engineering Education *6th to 8th April PARIS*
Second World Conference on Continuing Engineering Education, organized by the European Society for Engineering Education, to be held at UNESCO Headquarters in Paris. Information: Mr N. Krebs Ovesen, Danish Engineering Academy, Building 373, DK 2800, Lyngby, Denmark.

● ICAP '83 *12th to 15th April NORWICH*
Third International Conference on Antennas and Propagation organized by the IEE in association with the URSI, IEEE, IMA, IoP and the IERE, will be held at the University of East Anglia, Norwich. Information: IEE Conference Department, Savoy Place, London WC2R 0BL. (Tel. 01-240 1871, ext. 222)

***Engineering Softwere** *11th to 13th April LONDON*
Third International Conference and Exhibition on the Use and Applications of Computers in Engineering, will be held at Imperial College. Information: Conference Secretary, 125 High Street, Southampton, SO1 0AA (Tel. (0703) 21397)

Electrostatics *13th to 15th April*

OXFORD
Sixth conference on Static Electrification organized by the Institute of Physics in association with the Institution of Electrical Engineers, will be held at St Catherine's College, Oxford. Information: Meetings Officer, Institute of Physics, 47 Belgrave Square, London SW1. (Tel. 01-235 6111)

'ICASSP '83 *14th to 16th April BOSTON*
Eighth International Conference on Acoustics, Speech, and Signal Processing organized by the IEEE, will be held at the Sheraton-Boston Hotel, Boston, Massachusetts. Information: Publicity Chairman, Richard Kurth, Sperry Research Center, 100 North Road, Sudbury, MA 01776, USA. (Tel. (617) 369-4000)

MAY

Test and Measurement *2nd to 5th May SAN JOSE*
The Second Annual Test and Measurement World Expo will be held at the San Jose Convention Center. Information: Meg Bowen, Test and Measurement World Expo, 215 Brighton Avenue, Boston, MA 02134 U.S.A.

Noise *17th to 20th May MONTPELLIER, FRANCE*
Seventh International Conference on Noise in Physical Systems/Third International Conference on 1/f Noise, will be held in Montpellier, France. Information: Dr B. Jones, Department of Physics, University of Lancaster, (Tel. Lancaster 65201); or Professor H. Sutcliffe, Department of Electronic & Electrical Engineering, University of Salford.

Electron Tubes *18th to 20th May GARMISCH-PARTENKIRCHEN, F.R.G.*
Conference on Electron Tubes organized by VDE (NTG) in association with the German Section of the IEEE, will be held in Garmisch-Partenkirchen, Bavaria. Information: Conference Chairman, Dr H. Heynisch, Siemens AG, Werk fur Rohren und Sondergebiete, St Martinstrasse 76, D-8000 Munchen 80.

JUNE

IOOC '83 *27th to 30th June TOKYO*
The Fourth International Conference on Integrated Optics and Optical Fibre Communication, sponsored jointly by the Institute of Electronics and Communication Engineers of Japan and the Institute of Electrical Engineers of Japan, will be held at Keio Plaza Hotel, Tokyo. Information: Y. Suematsu, Department Elec. Phys. Tokyo Institute of Technology, 2-12-1, O-okayama, Meguro-ku, Tokyo, 152 Japan.

JULY

'Reliability '83 *6th to 8th July BIRMINGHAM*
Fourth National Reliability Conference organized by the National Centre of Systems Reliability in association with the Institute of Quality Assurance, will be held at the National Exhibition Centre, Birmingham. Information: Mr A. Cross, National Centre of Systems Reliability, UKAEA, Wigshaw Lane, Culcheth, Warrington WA3 4NE.

SEPTEMBER

'C.A.S.T. '83 *13th to 15th September BIRMINGHAM*
First International Conference and Exhibition on Cable and Satellite Television organized by Cable and Satellite Television Exhibitions, will be held at the Birmingham Metropole Hotel. Information: Exhibition, Michael Hyams, Managing Director, Cable & Satellite TV Exhibitions Ltd, 5 Barratt Way, Tudor Road, Harrow HA3 5QG. (Tel. 01-863 7726) Conference, The Economist Conference Unit, 25 St James's Street, London SW1 1HG. (Tel. 01-839 7000)

Weightech '83 *13th to 15th September LONDON*
Third International Industrial and Process Weighing and Force Measurement Exhibition and Conference, organized by Specialist Exhibitions in association with the Institute of Measurement and Control, to be held at the Wembley Conference Centre. Information: Specialist Exhibitions Ltd, Green Dragon House, 64/70 High Street, Croydon, CR9 2UH. (Tel. 01-686 5741) Conference Information: IMC, 20 Peel Street, London W8 7PD. (Tel. 01-727 0083).

Simulators *26th to 30th September BRIGHTON*
International Conference on Simulators, organized by the IEE, will be held at the University of Sussex. Information: IEE Conference Department, Savoy Place, London WC2R 0BL (Tel. 01-240 1871) *(Synopses by 4th October.)*

'★NEOS '83 *26th to 30th September READING*
International Conference on Networks and Electronic Office Systems, organized by the IERE, will be held at the University of Reading. Information: Professional Activities Department, IERE, 99 Gower Street, London WC1E 6AZ. (Tel. 01-388 3071) *(Synopses by 1st February 1983, Papers by 1st May 1983).*

OCTOBER

'Computer Graphics '83 *4th to 6th October LONDON*
Conference and Exhibition on Computer Graphics organized by Online Conferences. Information: Online Conferences Ltd, Argyle House, Northwood Hills, Middlesex HA6 1TS. (Tel. (09274) 28211).

Security Technology *4th to 6th October ZURICH*
17th Carnahan Conference on Security Technology, organized by the Institute for Communication Technology at the Eidg. Technische Hochschule Zurich, in association with the College of Engineering, University of Kentucky, will be held in Zurich. Information: P. de Bruyne, ETH Zentrum-KT, CH-8092 Zurich, Switzerland. (Tel. 411-2562792)

'Viewdata '83 *18th to 20th October LONDON*
Conference and Exhibition organized by Online Conferences. Information: Online Conferences Ltd, Argyle House, Northwood Hills, Middlesex HA6 1TS. (Tel. (09274) 28211).

Telecom '83 *26th October to 1st November GENEVA*
Second World Telecommunication Exhibition, organized by the International Telecommunications Union, to be held at the New Exhibition Conference Centre in Geneva. Information: Telecom '83, ITU, Place des Nations, CH-1211 Genève 20, Switzerland. (Tel. (022) 99 51 11).

Organizers of appropriate events are invited to submit details to the Editor for inclusion in this calendar.

MONITORING OF TRAINING

(See Editorial in this Issue, page 443)

I am interested in the possibility of acting as an adviser to members undergoing training at my place of employment (and/or elsewhere if conveniently accessible).
Please send me details of an adviser's role in implementing the IERE Training Requirements.

Name .... Class of Membership ....
(including title, qualifications, etc.) (Block Capitals Please)
Address ....

....

....

Position in company ....

Specialization (if any) ....

Employer's name ....

Address ....

Signature .... Date ....

Please complete and return to: Education Department, IERE, 99 Gower Street, London WC1E 6AZ.

(Photocopy if you do not wish to mutilate your Journal.)